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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

Reduced Railroad Fares

A LARGE percentage of the members of the Society are entitled to purchase transportation to the Annual and Chicago Meetings at a material reduction in cost. The saving in many cases will be sufficient to pay a member's dues for 1 year. Be sure to read the announcement on p. 131.

Gear Noise

TWO of the papers read at the Production Meeting contributed the experience of production engineers who have made careful investigations into the causes of gear noise. The paper by the Packard engineers, H. J. Crain and J. Brodie, advanced the theory that the anti-friction bearings supporting the gear shafts were fitted without sufficient clearance for an oil film, and that an increase of the clearance resulted in an appreciable reduction in the noise produced by the gears when in motion. In the discussion printed on p. 23, another authority corroborates the Packard experience with increased bearing-play, but advances a new explanation for the noise reduction that appears to be a logical one. Other valuable opinions are presented in the discussion of K. L. Herrmann's paper on p. 26.

Transportation

WHERE $1 is spent to haul a ton of freight by road wagon from New York City to Newark, N. J., a distance of 9 miles, that dollar will haul the same freight as far as Plainfield, N. J., or 24 miles over good roads, by motor truck. It will haul the same freight as far as Baltimore by steam railroad. It will haul this freight from New York City to the City of Washington, and back through canals and inland waterways. It will haul it across the Atlantic Ocean by ship.

Every time a producer in the West ships 2 carloads of grain to Liverpool more than 1 carload is absorbed in transportation charges.

Copper and zinc are now being shipped from Montana 800 miles by rail to the Pacific, thence through the Panama Canal and over 7000 miles by sea to Perth Amboy, N. J., at a cost which has been estimated at $5 per ton less than by an all-rail haul east, covering a distance of only 2500 miles.

At Detroit there is annually a rail movement of 25,000,000 tons. About 6,000,000 tons goes to seaboard points. Approximately 80,000,000 tons of freight passes through the Detroit River annully.—W. L. Saunders.

The Group-Bonus Plan

KARL WENNERLUND'S paper on the Group-Bonus Wage Incentive Plan was received with great interest by the men who attended the Production Meeting in Detroit. A number of questions were asked of Mr. Wennerlund at the meeting and answered by him in the discussion of the paper. These questions and answers, published in this issue of THE JOURNAL, are a valuable supplement to the paper itself. The effect of the group-bonus plan upon inspection methods is treated; the division of earnings among the workers in the group is explained; recommendations of the proper size of a group are made. Mr. Wennerlund tells what is done when a worker is discharged and how a new and untrained worker is added to the group. Endorsements of factory executives who have successfully applied the group-bonus plan are included in this discussion which will be found on p. 28.

Aeronautical Safety Code

IT is expected that at an early date regulatory legislation on the use of aircraft will be passed. Detailed regulations should not be included in statutes. This is one of the policies in accordance with which the Society and the Bureau of Standards, which are sponsors for the Sectional Committee on Aeronautical Safety Code, are proceeding. The customs and practices in aeronautics will require modification and change from time to time to keep pace with rapid progress of the industry. If no appropriate engineering standards exist at the time Governmental agencies are authorized to promulgate legal regulations, the latter will have to prepare something of the kind themselves. The Sectional Committee is endeavoring to have ready for use a safety code prior to the initiation of legal regulations, so that these can be based on the results of cooperative technical deliberation. Parts of the safety code have been outlined in a preliminary way. In this work over 200 persons other than members of the Committee have been consulted. It is the view of Chairman Crane that the Committee should consider carefully every matter of engineering importance in aviation, from the design and fabrication of the

aircraft to its piloting, and endeavor to formulate a sound recommendation with regard to it.

Cooperative Fuel-Tests

THE cooperative motor-fuel investigations of the American Petroleum Institute, the National Automobile Chamber of Commerce and the Society of Automotive Engineers, which have already borne results of great value, were made possible by the long, arduous and persistent study and advocacy of a few engineers and scientists who saw clearly what should be attempted and very generously devoted much of their knowledge and time for the common good. They made and revised again and again written statements of the salient points to be considered, and specified how these points should be studied, and how and at what cost the work to this end could be carried on. After many months of work the actual tests were started, splendid cooperation being given by the Bureau of Standards, and by many oil-refining and motor-vehicle producing companies. The Bureau of Standards had staunchly supported and aided the plan from the start, proceeding step by step with the Research Departments of the American Petroleum Institute and the Society of Automotive Engineers. The Bureau of Mines also has rendered valuable assistance.

Automotive Engineering Progress

THE publication of eight Annual Meeting papers in this issue of THE JOURNAL reflects active study being given automotive problems by those engaged in the engineering branch of our industry. They are representative of the manner in which automotive problems are being attacked today. It seems only a few years ago that automotive engineers were accused of applying cut-and-try methods in most of their work. Surely, careful reading of the papers of Messrs. Heron, Young, Kegerreis, Pulsifer and the others will convince one that scientific analysis has found its place among automotive men. The report of the cooperative research work on fuel-volatility should receive the fullest consideration of every engineer employing internal-combustion engines of the light-fuel type. The conclusions set forth have a bearing on the economics of our own industry and that of the petroleum refiners. Truly, this issue of THE JOURNAL records automotive engineering progress of the most creditable type and is deserving of more than average study.

Accidents from Another Viewpoint

THE annual toll of life due to accidents involving motor vehicles is a constant source of anxiety to the industry as well as to the public at large. The recent census returns giving the figures for deaths due to motor-vehicle accidents during the year 1921 has been the subject of much critical comment in trade journals and in the daily press. A perusal of these rather startling statistics raises the question as to their significance. Accidents are obviously dependent upon the density of traffic as well as on density of population.

The figure quoted for 1921, 10.13 fatalities per 100,000 of population as against that for 1917, 7.96 per 100,000 of population, shows an increase of 28 per cent in the death rate per 100,000 population. These figures, however, take account of the increase in population, but not of the increase in traffic.

It is necessary to look elsewhere for figures showing the density of traffic. In 1917 the total number of motor vehicles registered throughout the Country was 4,992,152, or practically 5,000,000. In 1921, the number was 10,505,660, an increase of 110 per cent. In other words, the density of traffic has increased more than three times as fast as the number of fatalities, or, expressed in another way, in 1917, 5,000,000 vehicles were responsible for 8,435 fatalities, and in 1921, 10,500,000 vehicles were responsible for 11,953 fatalities. In 1917, therefore, there were 169 fatalities per 100,000 vehicles as against 114 fatalities per 100,000 vehicles in 1921. In other words, the fatalities per 100,000 vehicles have decreased by roughly 33 per cent.

Commercial Airplane Design Fundamentals

WHAT characteristics must a satisfactory commercial airplane have to assure its operators an adequate return on their investment? Until this question is answered, commercial aviation will make little progress in this Country. Most engineers agree that the Air-Mail Service presents the most fertile field for the airplane at this time. Transportation of package freight is the next step and passenger carrying lies beyond. This seems to dictate the confining of design effort to mail and freight-carrying craft and a discussion of their basic features. Some agreement regarding the principal design and performance characteristics of these machines must be reached among aeronautical engineers before their efforts can be productive of a practical and economic design. Details may be varied to suit the whims of individuals but certainly there must be some fundamentals on which all should agree. The Society has arranged an aeronautical session during the Annual Meeting for the specific purpose of attempting to reach such an agreement. Those members who look upon the commercial application of the airplane in a serious light should avail themselves of this opportunity to express their opinions and foster, thereby, a common-sense attack upon the engineering and economic problems retarding commercial aviation.

Are Section Dues Justified?

SOME members of the Society object to paying dues to local Sections, feeling that their national dues entitle them to participate in Section activities and that the local dues are not justifiable as an added levy. A few minutes' study of the facts in the case should convince one that this attitude is incorrect. There are approximately 5300 members in the Society; only 3000 of these reside within commuting distance of the centers where there are organized Sections. The other members cannot enjoy Section privileges because of their geographical location.

The Society expends $2.95 per member on the Sections annually, $6,500 of the total Sections' budget for this fiscal year being in the form of direct appropriations to the several Section treasuries. This expenditure of a portion of the dues of members who do not reside near enough to headquarters of Sections to join them is justified only by the fact that the Sections produce valuable papers for THE JOURNAL which can be read and enjoyed by such members. Further expenditure of their dues for Sections' operations is, it is believed, not justified; the balance of the expense should be borne by members of the Sections who enjoy all the advantages of membership in them. They alone can attend the meetings, dinners and social functions and this service is worth the nominal sum charged by the Sections as dues. It seems clear that the total expense of the Sections cannot be levied equitably upon the national dues of all members regardless of their location. The proper solution appears to be to expect those who receive Sections service to pay something additional for it.

Society's Research Sheds New Light on Fuel Problem

By V. H. Gottschalk[1]

Annual Meeting Paper *Illustrated with* Charts

THE author describes a series of road service-tests, made of stock cars driven by their usual drivers when using fuel of specified grades, to determine the effect of any changes in the fuel volatility on the gasoline mileage for the respective make of car as part of a general research program undertaken jointly by the automotive and the petroleum industries. The object was to determine the best fuel as regards volatility, from the general economic standpoint, and what grade of fuel will afford the maximum car mileage per barrel of crude oil consumed in its production.

Factors influencing the selection of cars used are enumerated and the fuels tested are discussed, together with general comment and a description of the test procedure. The results are tabulated and commented upon at some length, inclusive of descriptions of the methods. A summary of the results is presented in the form of conclusions that are stated in four specific divisions. The value of statistical research is illustrated by the results obtained.

SOME months ago, a number of automobile producing companies, at the instance of the Society's Research Department, undertook a series of road service tests to determine the effect of any changes in the fuel volatility on the gasoline mileage for their respective makes of car. These tests were instituted as part of a general research program undertaken jointly by the automotive and the petroleum industries to find an answer to the question, "What is the best motor-fuel, as regards volatility, when considered from the point of view of the general economic situation?" Perhaps the most important phase of this question is, "What grade of fuel will afford the maximum mileage per barrel of crude oil consumed in its production?" The tests here described were intended to answer this question with reference to a number of makes of passenger car when used in normal service under the general supervision of the experimental departments of their respective builders.

To make the results as nearly comparable as possible, and to furnish a central office for the collection and correlation of the results, the following general plan of procedure was formulated by the Research Department in consultation with a number of companies. While each of the individual laboratories was at liberty to modify the plan as desired, as a matter of fact, the original schedule was followed closely in nearly all instances.

The general plan was to operate as large a number of stock cars as practicable successively on each of four specified grades of fuel, the cars to be driven by their usual drivers, in most cases owner-drivers, in the regular course of service, and to secure accurate records of the fuel-consumption, the mileage and the oil consumption and of the crankcase-oil dilution when practicable.

The question of carbureter adjustment, which is obviously of primary importance, had to be handled differently in different cases because of the divergence of the types of carbureter equipment in the various makes of car. Records of the oil consumption and the crankcase dilution were made by some companies and not by others.

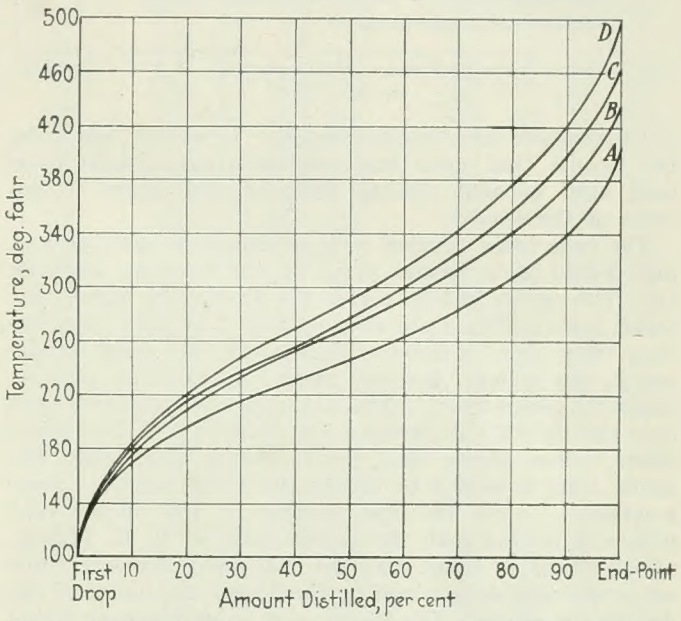

Fig. 1—Distillation Curves of the Four Fuels Used in Tests

The general conduct of the tests as carried out with only minor variations by all of the 10 companies was as follows:

Cars

Cars were selected for the tests in groups of four so far as possible. The reason for this arrangement in fours will appear later. These cars were, for the most part, owned and driven by officials of the companies, although in a few cases they were test cars or service cars belonging to the companies. They were selected with a view to being typical of the cars of that particular model in actual use throughout the Country. Therefore, they were cars that had received no special overhaul or preparation, except in a few cases where their condition demanded it before starting the tests. These tests involved 4 weeks of operation without any special attention or adjustment, except as to the carbureter for using different fuels.

The number of cars selected by the different companies varied from 4 to 12, and represented from one to three different models.

Fuels

In the selection of fuels of different volatilities for these tests several of the oil companies were consulted, and it was finally decided to specify four grades of fuel as nearly similar as possible except as to the volatility of the heavier fractions, but covering a volatility range as wide as was considered practicable for use in standard

[1] M.S.A.E.—Research engineer, Society of Automotive Engineers, Inc., New York City.

RECORD OF CARS IN THE TESTS

Car No.	Age	Total Mileage	When Last Overhauled	Carbureter*	Remarks
1					
2					
3					
4					
5					
6					
7					
8					

Please state whether or not carbureter setting was changed for the different fuels and, if so, the method used for making the settings

** Note make and model of carbureter*

FIG. 2—FORM USED IN RECORDING PARTICULARS OF THE CARS USED IN THE TEST

carbureter and manifold equipment. It will be seen from the results that even less volatile grades might have been used without serious difficulty and added to the value of the results.

The four fuels selected were produced in quantity and distributed at a special price by the Sinclair Refining Co. The curves in Fig. 1 give the distillation figures for these fuels. They were produced by a straight distillation from four different batches of the same crude, which, we believe, insured their similarity as regards chemical composition. The original specifications fixed only the 10 and the 90-per cent points of the distillation curve. The 10-per cent points, being practically the same, were intended to insure the same starting characteristics, while the specification of the 90-per cent points is in line with the recent work of R. E. Wilson, which seems to show that the heavy-end characteristics are practically determined by the 85-per cent point of the distillation curve. The 90-per cent point represents this almost as well as the 85-per cent point and is one of the regular test-points.

These fuels were sent out under labels *A*, *B*, *C* and *D*, in order of the increasing end-point. Careful precautions were taken by all the companies to avoid mistakes in the records involving the grades of fuel. Samples of the four grades were sent to the Bureau of Mines for check-tests, and in most cases the companies' laboratories made their own tests for verification of the labels.

DRIVERS

As stated before, most of the drivers were owners of the cars they drove, but some of the cars were service or test cars driven in accordance with the usual procedure. Provision was made to insure that the drivers should have no information as to the grade of fuel in use at any particular time. This was considered important to avoid prejudice. To what extent this requirement was actually carried out, we have no means of determining, but an examination of the results satisfies us that they are free from any such effect as a preconceived opinion on the part of the driver.

RECORD FOR WEEK BEGINNING..... ENDING.....

CAR NO.	FUEL	MILEAGE, START	MILEAGE, FINISH	MILES COVERED	GAS, START	GAS, FINISH	GAS USED	OIL* USED	OIL SAMPLE MARK	REMARKS

CARS: 1,2,3,4,5,6,7,8 FUELS: A,B,C,D

First Week: 1 and 2 use fuel A; 3 and 4 use fuel B; 5 and 6 use fuel C; 7 and 8 use fuel D
Second Week: 1 and 2 use fuel B; 3 and 4 use fuel C; 5 and 6 use fuel D; 7 and 8 use fuel A
Third Week: 1 and 2 use fuel C; 3 and 4 use fuel D; 5 and 6 use fuel A; 7 and 8 use fuel B
Fourth Week: 1 and 2 use fuel D; 3 and 4 use fuel A; 5 and 6 use fuel B; 7 and 8 use fuel C

** If lubricating oil is changed for each week's run, record the total amount of apparent consumption by substracting the amount drained from the amount put in.*
If any test is made for dilution, enter results under remarks
Retain samples of new oil and each used oil

FIG. 3—WEEKLY RECORD FORM OF TESTS

TEST PROCEDURE

The test procedure recommended and followed in all cases, with only minor changes, is explained in Figs. 2 and 3. The prime object in carrying out this procedure was to eliminate, so far as possible, the disturbing effects of any differences in the weather and in the types of driving, by a careful selection of a schedule in which they would cancel out, considering the fact that the results derived are merely representative of the differences in mileage for the different fuels. For this reason, a unit of time of 1 week was selected on the general assumption that the normal driving conditions are more likely to be alike from week to week than for any arbitrary period of a different number of days.

The effect of any changes in the weather and of any progressive changes in the condition of the cars was eliminated so far as possible by the schedule of tests. The elimination of systematic errors of this kind is one of the most important features of such a test program.

RESULTS

The nine companies cooperating in the tests used 55 automobiles for 207 separate test-periods of 1 week, averaging 262 miles each. The total mileage, 54,258, was distributed as shown in Table 1, the shortest run being 41 miles and the longest 1111 miles.

TABLE 1—DISTRIBUTION OF MILEAGE IN TEST RUNS

Distance, Miles	Number of Runs
41-99	13
100-199	61
200-299	72
300-399	40
400-499	11
500-599	3
600-699	0
700-799	3
800-899	0
900-999	2
1000-1111	2

The figures for the gasoline mileage, the lubricating-oil mileage and the crankcase dilution are given in Tables 2, 3 and 4.

The second to fifth columns inclusive of Table 2, and Table 3 contain all results reported on the gasoline mileage; the second to fifth columns of Table 2 give the figures arranged in order of the increasing mileage with *B* fuel, which most closely approximates the average filling-station gasoline; Table 3 gives the ton-miles per gallon arranged to show all the group tests, each group consisting of from three to five cars of the same model; the nine cars for which no figures are given in Table 3 include one group of three cars of widely different types, a single ½-ton truck, a seven-passenger phaeton and a commercial car, as well as three closed cars belonging to groups 1 and 9. The last three columns of Table 3 express the individual group-averages as percentages of the corresponding *B* average.

The last four columns of Table 2 record all of the figures reported for the apparent oil-consumption and

are not corrected for the crankcase-oil dilution. Table 4 gives the results on the latter.

Gasoline Mileage

The averages at the bottoms of the second to fifth columns of Table 2 are approximately equal, the maximum difference being only 1.6 per cent. A graphical comparison of the numbers in the column headed *B* with those in the columns headed *A*, *C* and *D* is given in Fig. 4 where the *B* values are measured along the horizontal lines *OO* and the deviations of *A*, *C* and *D* are plotted vertically above or below the corresponding *B* value according as these deviations are positive or negative; that is, in Fig. 4 the abscissas for each one of the three graphs are the *B* values given in the third column of Table 2, while the ordinates are the differences between the *B* value and the corresponding *A*, *C* or *D* values. It will be noticed that the points along the same vertical line cutting all three graphs represent the same car. The method of plotting used for Fig. 4 assumes that the *B* values are correct, and thus distorts the actual variations in *A*, *C* and *D*. In presenting the results in this manner, any variation in the gasoline mileage due to a change from the standard fuel *B* will be accentuated, and it is with the object of facilitating the detection of such variations that this unfavorable representation of the *A*, *C* and *D* runs has been prepared. On this understanding, we may deduce the following facts from Fig. 4:

(1) There is no tendency of the points on any of the three plots to drift from a higher value than *B* at either end of the series to a correspondingly lower value at the other end

(2) The horizontal spacing of the points is not uniform, there being a dearth of points particularly at the higher mileages and to a lesser extent at the lower mileages

(3) At the points *r*, *s*, *u* and *v* of Fig. 4, the *B* values are much higher than the corresponding values for *A*, *C* and *D*

(4) There is a slight, but nevertheless unmistakable, tendency for the *B* values to be the highest of the four

What is meant by item (1) is that an oblique line like *lm* or *pq* does not represent the assemblage of points as well as does the horizontal line, and we may conclude that *A*, *C* and *D* are equivalent to *B* as regards gasoline mileage, not only on the average for all cars, but over the whole range of mileages from 9.5 to 22.5 miles per gal., except possibly at the ends.

The evidence from Fig. 4 supplements the arithmetical equality of the averages for fuels *A*, *B*, *C* and *D*, by demonstrating that the observed mileages for *A*, *C* and *D* oscillate about the corresponding *B* observations practically at random. We are justified therefore in asserting that, within the degree of accuracy attained in the cooperative fuel-test, the gasoline mileage is not dependent on the fuel volatility within the range shown by fuels *A* to *D*, except, again, possibly at the ends of the range.

A part of the condition mentioned in (2) is due to the method of plotting, as for instance the last point, which happens to have a very high *B* value coupled with unusually low *A* and *D* values. Even when the figures are replotted as deviations from the average for each car, the points are more closely packed in the range from 11 to 19 miles per gal. than at the ends. No attention need be paid to this thinning-out of points at the ends, if we may assume that additional runs with cars giving from 8.5 to 11.0 and from 19.0 to 21.5 miles per gal. would yield points which, when plotted, would oscillate about *B* in the same manner as shown for the inner ranges of the graphs; if we wish to be conservative, however, we might qualify the assertion made at the end of the preceding paragraph so as to limit the conclusion to mileages between 11 and 19.

TABLE 2—GASOLINE AND APPARENT LUBRICATING OIL MILEAGES

No. of Car	Miles per Gallon of Gasoline				Apparent Miles per Gallon of Lubricating Oil			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*
1	10.73	9.43	12.77	11.62	570	344	1,490	494
2	9.29	9.88	9.02	8.39	...	...	...	...
3	...	10.18	...	...	...	...	...	...
4	...	...	8.54	8.37	...	...	...	...
5	14.07	10.31	12.83	10.85	...	...	...	...
6	8.00	10.63	8.75	13.66	...	...	...	...
7	10.50	10.81	11.39	11.79	...	...	...	...
8	11.21	...	...	...	...	...	...	...
9	12.19	11.52	11.68	12.08	300	287	347	315
10	11.57	12.00	11.57	12.91	...	...	...	...
11	12.57	12.37	9.66	8.76	622	583	418	671
12	12.53	12.45	12.55	12.70	720	265	756	1,720
13	11.19	12.80	12.34	12.62	535	593	520	1,245
14	13.49	12.92	12.68	12.27	1,781	1,344	1,381	1,600
15	9.19	13.13	8.31	7.94	...	...	...	...
16	14.03	13.29	14.40	14.19	...	...	...	...
17	13.05	13.30	14.10	14.08	287	195	576	334
18	13.78	13.35	13.95	12.50	523	1,236	382	768
19	14.58	13.45	13.76	14.62	1,655	...	2,100	754
20	13.70	13.85	15.05	13.15	366	790	872	1,088
21	12.48	13.90	12.28	14.15	...	633	1,218	598
22	...	...	14.12	...	...	...	...	...
23	14.06	14.13	15.48	15.83	...	...	...	...
24	12.87	14.17	14.42	13.59	263	244	232	214
25	14.34	14.38	15.14	14.05	441	412	446	450
26	12.28	14.58	13.70	12.65	400	407	564	504
27	15.86	14.61	15.70	19.98	...	...	...	...
28	13.90	14.82	14.45	15.00	780	637	1,260	1,320
29	15.02	14.98	16.19	14.79	1,352	1,152	475	1,225
30	15.10	15.15	16.50	16.10	826	793	792	1,168
31	16.85	15.35	16.73	15.35	574	570	735	532
32	15.25	15.38	15.00	17.20	319	2,860	...	1,770
33	15.22	15.45	15.65	14.90	530	248	826	1,060
34	16.50	15.50	15.90	15.72	527	584	740	...
35	14.14	15.54	15.83	17.19	386	525	275	352
36	15.70	16.35	16.83	13.75	419	820	731	710
37	16.29	16.35	15.23	16.00	414	533	528	1,944
38	12.50	16.45	12.27	13.45	533	...	1,211	416
39	14.50	16.48	14.40	...	675	(*a*)	1,625	...
40	15.75	16.52	14.92	14.90	...	...	...	...
41	14.06	16.58	14.65	14.52	870	3,290	2,099	1,730
42	16.06	16.59	16.40	16.76	...	...	...	...
43	17.42	16.72	17.60	16.59	832	...	1,408	...
44	16.61	...	17.52	17.37	...	...	...	...
45	18.08	17.02	15.38	16.81	...	...	...	...
46	14.13	17.13	14.72	14.19	520	480	537	517
47	18.47	17.24	18.63	15.54	505	776	484	2,539
48	18.18	17.41	17.08	18.01	...	...	...	...
49	18.86	18.37	17.58	18.79	347	269	313	376
50	20.34	18.48	17.94	17.90	374	389	437	990
51	19.90	18.58	17.10	19.15	1,885	2,195	(*a*)	3,520
52	21.50	19.30	19.68	18.61	872	1,032	(*a*)	99
53	23.58	19.59	19.41	20.58	566	431	526	343
54	22.04	21.00	21.03	21.78	353	988	622	686
55	16.66	22.48	20.13	16.32	400	438	352	(*a*)
Average	14.81	14.94	14.70	14.71	648	768	803	910

(*a*) More oil at the end of the run than at the start.

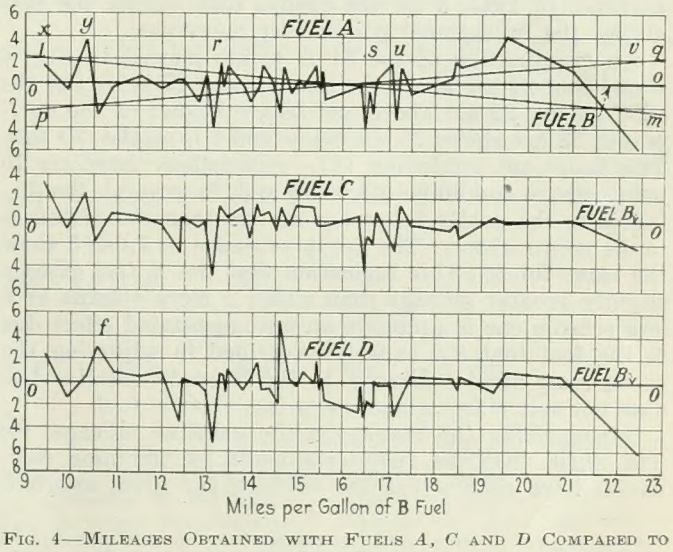

FIG. 4—MILEAGES OBTAINED WITH FUELS *A*, *C* AND *D* COMPARED TO FUEL *B*

The condition mentioned in (3) is partially neutralized by low B values at x and y and by the two isolated high D values at f and g. These exceptional values should not be regarded as being in error, as it is an inevitable consequence of the conditions under which the test was conducted that there are occasional runs showing abnormally good or bad performance; the scheme of using groups of cars was planned to distribute these occurrences among the four fuels evenly.

How this compensation was to be accomplished with a minimum number of test-runs may be understood from the following schedule according to which the cooperating companies agreed to conduct their tests.

	First Week	Second Week	Third Week	Fourth Week
Car 1	Fuel A	Fuel B	Fuel C	Fuel D
Car 2	Fuel B	Fuel C	Fuel D	Fuel A
Car 3	Fuel C	Fuel D	Fuel A	Fuel B
Car 4	Fuel D	Fuel A	Fuel B	Fuel C

This scheme provides for eliminating all daily variations by giving a weekly average for each car on each fuel; it compensates for any weekly variations, in the weather for example, by requiring all four fuels to be in use throughout the whole time; it anticipates the effect of any progressive change in the driving properties of each car by preserving a systematic rotation of the fuels for each week. The group average, then, may be regarded as representative of the performance of the particular type of car used in each group.

A closer examination of the abnormal places marked on the graphs, especially when considered in relation to the group runs, indicates that the reservation made in (2) above is of consequence only at the high-mileage end, because the first seven or more points at the low-mileage end represent a heterogeneous set of cars; of various makes, weights and ages, no two of which belong to the same group, and because the abnormal points in the inner range are surrounded by points from the same group, while, on the contrary, the last five points on the high-mileage end all belong to two groups of cars typical of the lightest-weight automobiles. It is possible, as far as may be judged from the mileages reported for cars going 19 or more miles per gal., that additional data on such high-mileage automobiles might reveal a definite, but slight, difference in the mileage with fuels of different volatilities.[2] That this compensation has been realized to a great extent may be seen by examining the averages in Table 3 for the groups that include the cars giving the exceptional points just mentioned.

An examination of the 51 A points plotted in Fig. 4 shows that 24 are above the line OO and 27 below; of the 50 C points, 22 are above and 28 are below; of the 49 D points, 23 are above, 25 are below and 1 is on the OO line. This bears out conclusion (4). Altogether, there are 70 points above and 80 points below and, in general, the distances to the points below are no less than the distances to the points above. The group averages in Table 3 show the same thing. This indication that the B fuel gives a slightly greater mileage than either a more volatile or a less volatile one is probably an uncompensated effect due to the fact that the experience gained in adjusting the carbureters applies directly to the B-grade gasoline but does not suit either a more or a less volatile fuel.

Summarizing the results on the gasoline mileage, we find, then, that the fuel tests made by the nine companies have shown that the average car gives approximately the same mileage with the A, B, C or D fuels in warm weather.

[2] The Bureau of Standards test-results bear on this question, as three of the four cars used by the Bureau of Standards fit in at the high-mileage end.

Limits of Accuracy of the Fuel Test

Now that it is evident from Fig. 4 that in any column the mileages oscillate about the corresponding figures in the B column, we may eliminate the influence of the different cars. We have done this by expressing the group averages of Table 3 so as to represent the number of ton-miles that each car would have run on the same quantity of fuel as was used to get 100 ton-miles with the B gasoline. The advantage of recalculating the results in this way is that we now have, for each one of the three fuels, a series of values that oscillate about the same number, very near 100, throughout the whole range. This oscillation of the percentage numbers about a mean, suggests the possibility of assigning a limit of accuracy within which the numbers, when considered as representing independent observations of the same quantity, establish the mean of the series as the best value.

There are a number of ways of expressing this limit of accuracy, but all of them involve the same two factors, namely, the deviations of the separate observation from the mean, and the total number of observations; we have chosen the least optimistic of these indicators, the mean square of the deviations.

The last three columns of Table 3 give the percentages of the ton-mileage secured with fuels A, C and D when compared with the corresponding B ton-mileage as 100; under the mean for each column are given the mean deviations of the mean and of a single observation as calculated by the usual formulas.

$$D_s = \vee [S/(n-1)]$$
$$D_m = \vee \ (S \div [n(n-1)])$$

where

D_m = the mean deviation of the mean
D_s = the mean deviation of a single observation
n = the number of observations
S = the sum of the squares of the deviation from the mean

The mean deviations of the mean are ± 1.6, ± 2.3 and ± 2.6; the large discrepancies in the C and D averages of groups 4 and 5 account for nearly half of these mean deviations.

According to these calculations, we may claim an accuracy of no more than 2.6 per cent either way. That is, while the individual values show extreme variations, up to nearly 40 per cent in two isolated instances, the average of the variations from the group mean are well below 8.0 per cent and the compensation afforded by the group scheme in 12 cases has made the final result, reliable to about ± 2.6 per cent. From this mean deviation we may infer that if A, C or D were more than 2.6 per cent better or worse than the B fuel in producing mileage, the cooperative fuel-test as conducted would have detected the difference.

These results furnish a good illustration of the value of statistical research. The 55 cars employed in this test not only embodied various elements of design, but were in all sorts of condition. Some were new; others had been run 30,000 to 45,000 miles. In one set of 12 cars the carbureters were adjusted for each fuel by the same engineer; in another set of 12 cars the carbureters were adjusted at the beginning and not touched thereafter; a number of the companies depended on the drivers to make whatever adjustments were deemed necessary for best performance. Some cars were provided with hot-spots, stoves and similar devices. In a number of cases the week's regular run of a certain car

was changed from its city route to several days' road-work in the country and vice versa. Other variable factors were the weather conditions, possible mistakes in the speedometer and the fuel-volume readings, errors in the transcription of the records, reliability of the measuring instruments and the varying personal element represented by 55 different drivers. The analysis of the results here presented gives evidence that the cooperative fuel-test as conducted was successful in leading to mean values in which the compensation between this host of accidental variations is highly satisfactory.

Summarizing the accuracy calculation, we can say that ± 2.6 per cent may be assigned as an outside limit to the accuracy within which the conclusion concerning the gasoline mileage may be accepted as correct; and this limit is wide enough to include the results with the lightest cars for which the number of observations is not as great as could be wished.

Drivers' Comments

Three of the cooperating companies inserted their drivers' comments on the relative performance of their cars with the separate fuels. The comments of these 25 drivers indicated that greater volatility of the fuel leads to a greater ease and satisfaction in driving, while a high-end point gasoline, such as *D*, induces "spark-knock," slowness in warming-up, sluggish acceleration and other difficulties. One driver considered all four fuels about the same, and in two other instances only did the driver's order of preference not conform to the order of volatility, *A, B, C, D*.

The three companies reporting drivers' comments represented the heaviest and the lightest cars and one of the medium-weight models, and it may be not wholly a coincidence that the drivers of the heavy car were least disturbed about the differences in the fuels, while the drivers of the light car actually complained about the *D* fuel.

Oil Consumption and Crankcase-Oil Dilution

The figures for the apparent miles per gallon of lubricating oil are listed in the last four columns of Table 2. Records of oil consumption are not available for 25 of the 55 cars tested, and in four instances there is an increase rather than a decrease in the volume of oil in the crankcase. Despite the wide range of variation, the

TABLE 3—TON-MILES PER GALLON OF GASOLINE BASED ON A LOAD OF TWO PASSENGERS OF 150 LB. EACH

Group	*A*	*B*	*C*	*D*	Group Averages *A*	*B*	*C*	*D*	Expressed in Terms of *B* as 100 per cent *A*	*C*	*D*
1	24.7	24.8	27.0	26.3							
	24.8	25.2	25.6	24.3							
	21.3	21.7	23.0	23.0	23.6	23.9	25.2	24.5	98.8	105.3	102.4
2	23.7	24.2	23.6	24.5							
	22.4	22.6	24.6	21.5							
	25.6	26.8	27.5	22.4	23.9	24.5	25.2	22.8	97.5	102.8	93.2
3	27.0	25.3	26.0	25.6							
	20.4	22.7	20.1	23.1							
	20.5	20.3	20.5	20.8							
	22.6	21.8	22.8	20.4	22.6	22.5	22.4	22.5	100.3	99.5	100.0
4.	23.2	24.7	22.5	20.9							
	27.9	....	....	....							
	28.9	29.9	28.9	32.2							
	23.0	32.7	20.7	19.8							
	....	....	21.3	20.9	25.8	29.1	23.4	23.5	88.6	80.5	80.8
5	23.2	21.9	23.8	23.4							
	23.2	23.4	25.6	26.2							
	27.4	....	28.8	28.7							
	26.2	24.1	25.9	32.9	25.0	23.1	26.0	27.8	108.2	112.6	120.4
6	19.2	17.2	17.6	16.6							
	21.0	17.5	17.3	18.4							
	19.7	18.8	18.8	19.4							
	14.9	20.1	18.0	14.6	18.7	18.4	17.9	17.2	101.7	97.3	93.5
7	14.6	16.3	16.6	15.6							
	16.2	17.8	18.2	19.7							
	16.2	19.7	16.9	16.3							
	21.6	21.1	20.2	21.6	17.2	18.7	18.0	18.3	92.0	96.2	97.9
8	24.0	24.8	24.5	25.1							
	27.0	25.4	23.0	25.1							
	23.6	24.7	22.3	22.1							
	27.2	26.0	25.6	26.9	25.5	25.2	23.9	24.8	101.2	94.8	98.5
9	20.0	23.6	20.8	20.6							
	....	....	20.2	....							
	21.6	21.8	21.3	24.4	20.8	22.7	20.8	22.5	91.7	91.7	99.2
10	23.4	22.4	21.9	21.2							
	21.6	28.4	21.2	23.2							
	....	17.6	....	....							
	21.2	25.2	23.6	21.8	22.1	23.4	22.2	22.1	94.5	94.9	94.5
11	19.3	22.1	21.3	21.8							
	26.1	25.9	27.8	25.6							
	25.0	25.0	26.2	24.2							
	20.9	19.9	20.2	20.9	22.8	23.2	23.9	23.1	98.3	103.1	99.5
12	29.5	26.3	25.6	25.5							
	26.3	24.5	26.6	22.2							
	23.2	23.4	21.7	23.8							
	24.8	23.8	25.1	23.6	25.9	24.5	24.8	23.8	105.7	101.3	97.2
				Average	22.8	23.3	22.8	22.7	Means 98.2	98.3	98.1
						Mean deviation of the mean			±1.6	±2.3	±2.6
						Mean deviation of single observation			±5.8	±7.9	±8.9

TABLE 4—CRANKCASE-OIL DILUTION

Fuel	A		B		C		D	
Group	Percentage Distilled Off[3]	Viscosity[4]	Percentage Distilled Off[3]	Viscosity[4]	Percentage Distilled Off[3]	Viscosity[4]	Percentage Distilled Off[3]	Viscosity[4]
Set 1								
9	4.5	176	6.5	160	8.0	138	14.0	105
	8.0	138	9.5	124	11.0	116	15.5	93
	8.0	137	10.0	126	14.0	111	22.0	85
	8.0	127	14.5	103	17.0	94	21.0	78
Group Average	7.1		10.1		12.5		18.1	
10			9.0	116				
	9.0	118	11.5	110	13.0	100	13.0	106
	5.5	140	10.5	115	7.0	146	10.0	120
	8.0	195	7.0	185	16.0	160	17.0	165
Group Average	7.5		9.5		12.0		13.3	
12	7.0	130	7.0	129	8.5	128	14.0	103
	7.0	130	7.0	127	10.0	120	13.5	100
	10.5	139	11.5	111	12.5	104	21.0	81
	5.5	145	7.5	128	7.5	128		
Group Average	7.5		8.3		11.3		16.1	
Average of the three Groups	7.4		9.3		11.3		16.1	
Average of the Groups Recalculated to Percentage Dilution	8.0		10.2		12.7		19.2	
Set 2								
1	7.0	202	8.5	196	10.4	173	12.5	154
	6.5	206	8.3	184	11.0	158	11.2	155
	7.5	184	8.5	152	13.4	140	16.0	125
	5.0	233	6.5	208	8.5	206	12.5	149
Group Average	6.5		8.0		10.8		13.1	
2	7.5	187	5.5	225	12.0	165	17.7	113
	9.0	179	13.5	144	12.9	132	15.5	125
	4.4	243	8.0	202	10.3	170	10.5	162
	5.2	219	8.5	192	12.5	158	13.0	138
Group Average	6.5		8.9		11.9		14.2	
3	6.0	223	7.5	190	9.5	177		
	5.5	221	6.3	214	6.5	206	8.7	189
	5.5	247	5.5	233	9.8	178	15.0	128
	7.2	197	8.0	187	10.5	164	13.0	140
Group Average	6.1		6.8		9.4		13.2	
Average of the Three Groups	6.4		7.9		10.6		13.2	
Average of the Groups Recalculated to Percentage Dilution	6.8		8.6		11.9		15.2	
Set 3								
8	7.8	326	5.8	405	10.0	290	19.0	158
	5.0	380	8.0	353	10.5	293	17.5	180
	8.5	335	4.5	439	12.0	259	24.5	123
	7.5	364	7.8	346	11.5	265	27.0	99
Group Average	7.2		6.5		11.0		22.0	
Average Recalculated to Percentage Dilution	7.8		6.9		12.4		28.2	

Original Oil

	Set 1	*Set 2*	*Set 3*
Specific Gravity	0.903	0.917	0.935
Viscosity at 100 Deg. Fahr., Saybolt sec.	201	301	633
Boiling Point, deg fahr.	572	590	545
Flash Point, deg. fahr.	385	382	380
Fire Point, deg. fahr.	450	438	435
Pour Test, deg. fahr.	...	23	15
Demulsibility	...	26	25
Brand of Oil	S. O. Indiana Formula No. 2999 Engine Oil	Medium Heavy Polarine	..

[3] Dilution figures are given as percentage of gasoline distilled from the crankcase oil.
[4] Saybolt viscosity at 100 deg. fahr.

averages for the *A*, *B*, *C* and *D* columns show a progressive decrease in the apparent consumption as the volatility of the fuel decreases. The extent of crankcase dilution cannot, of course, be deduced from the apparent oil-consumption, but this can be obtained by the use of test figures on the oils drained from the crankcases of 28 of the cars at the end of each period.

The percentages of gasoline distilled from the samples of crankcase oil are given in Table 4, which records also the constants of the three original lubricating oils and the Saybolt viscosities of the oils at 100 deg. fahr. These dilution figures may be taken as fairly representative, because, of the 12 groups of cars given in Table 3, seven are included in the table of dilution figures, three each in Sets 1 and 2 and one in Set 3.

The averages for the percentages of gasoline distilled from the crankcase oils are given for these seven groups, which are numbered to conform to Table 3; also, the general averages for the three sets of analyses have been taken and these latter figures are recalculated to show the actual dilution, that is to say, the percentage of gasoline based on the original oil.

In all cases but one, *A* to *B* in Set 3, the dilution increases progressively from *A* to *D*, with a distinct tendency to show a maximum difference between *C* and *D*.

The unfavorable position of fuel *D* as regards crankcase-oil dilution has a vital bearing on the question which the fuel test was expected to answer. This dilution factor assumes an even more important aspect when it is considered that the tests were all run during the summer months, and for this reason the final conclusion has been deferred to await the results which will be obtained from a projected continuation of the test under cold-weather conditions.

Summary

The conclusions drawn from the results of the tests can be summarized as follows:

(1) The ordinary passenger automobile, driven in the summer, shows no difference in the number of miles per gallon that can be obtained with gasolines of volatilities varying within the limits represented by fuels *A* to *D*. This conclusion has been shown to hold to within ± 2.6 per cent

(2) Drivers preferred the *A* and *B* gasolines; they did not object particularly to the *C* gasoline; most of them noted difficulty in driving their cars when using the *D* gasoline

(3) Crankcase-oil dilution increases progressively with a decreasing volatility, and the rate of increase is more marked for the heavier fuels

(4) The high crankcase-oil dilutions, among other things, have indicated the desirability of resuming the tests in the winter months

NUMBER AND TONNAGE OF MOTORSHIPS

ONE of the most interesting and significant maritime developments since the war is the rapid increase in the number and tonnage of motorships, an increase that seemingly has not been interrupted even by the extreme depression of the shipping industry during the past 2 years. According to the latest statistics available, during the 12 months ended June 30, 1922, in spite of the severe shipping depression, the tonnage of full-powered motorships of 2000 gross tons or over increased 37 per cent, as against a gain of only 4 per cent for steam tonnage exclusive of motorships. Perhaps, it is because of the shipping depression that the Diesel-engined vessel, with its unquestioned economies in operation, is being so rapidly adopted. On June 30, 1921, there were in the merchant fleets of all countries 145 motorships of 2000 gross tons or over, aggregating 692,000 gross tons; on the same date this year there were 186, totaling 946,000 tons.

The United Kingdom continues to lead, with 336,000 tons on June 30, 1922, an increase of 24 per cent. Sweden registered a large percentage gain but continues in third place. Norway has displaced the United States as fourth on the list. Germany, which did not have enough motorship tonnage to appear separately in the list last year, has this year seven Diesel-engined vessels aggregating 32,083 tons. Danzig has two ships aggregating 12,078 tons; one of these is the Zoppot, of 9932 tons, one of the largest tankers in the world.

The following table gives the number, tonnage and distribution of motorships of 2000 gross tons or over on June 30 of each of the years 1920, 1921 and 1922:

	1920		1921		1922	
Countries	Number	Gross Tons	Number	Gross Tons	Number	Gross Tons
United Kingdom	19	108,713	34	217,104	52	335,766
Denmark	16	93,295	21	121,580	22	129,507
Sweden	14	63,951	20	91,681	27	123,753
Norway	19	68,750	21	85,032	27	120,442
United States	22	59,807	28	86,457	30	101,672
Italy	5	24,102	6	26,449	7	36,476
Other	12	43,071	15	63,467	21	98,325
Totals	107	461,689	145	691,770	186	945,941

The above totals are what may be termed seagoing ships. In addition to these, there were 605 vessels under 2000 tons each, aggregating 234,325 tons, which were equipped with Diesel engines. Last year, on the same date, however, there were only 553 vessels of this kind afloat in various parts of the world, and their tonnage totaled 216,110 tons.

The chief engineer of one of the largest British shipyards stated 2 years ago that he saw a promising future for sailing ships with auxiliary Diesel-engine power. This kind of tonnage has increased from 45 ships, totaling 13,000 tons on June 30, 1915, to 777, of 342,530 tons, in 1921, and to 870, of 353,181 tons, in 1922. The United States holds the lead in this kind of tonnage, with 54 ships aggregating 50,957 tons.—*Economic World.*

Annual Report of the Treasurer

THE report of Treasurer C. B. Whittelsey, prepared in connection with the holding of the 1923 Annual Meeting of the Society, is presented herewith. This report covers the fiscal year ended Sept. 30, 1922, and similar figures for the previous fiscal year are included to enable the members to compare the various items readily. The estimated budget for the current fiscal year ending Sept. 30, 1923, is also presented.

	Fiscal Years 1921	1922
The annual audit of Rankin & Co., public accountants, as of Sept. 30, lists the assets of the Society at	$156,183.80	$154,322.23
They consisted of		
Cash	12,155.13	17,619.66
Accounts Receivable	26,806.93	29,544.64
Government and Railroad Bonds	83,194.38	76,513.13
Accrued Interest	909.30	2,284.04
Inventories	19,460.84	13.888.39
Furniture and Fixtures	8,850.08	8,533.08
Deferred Debit Items	4,807.14	5,939.29
	$156,183.80	$154,322.23
These were offset by		
Accounts Payable	$5,107.77	$20,321.18
Deferred Credit Items	2,760.28	2,868.53
Special Reserves	9,398.54	8,527.86
Total Liabilities	$17,266.59	$31,717.57
Unexpended Reserve on Sept. 30, of each year	$138,917.21	[a]$122,604.66

[a]After deducting deficit $15,327.83 and adjustment $984.72.

The income from operation during the fiscal year ended Sept. 30, amounted to	$229,778.90	$235,009.87
This includes		
Initiation Fees	19,265.00	11,470.00
Dues and Subscriptions	76,456.50	77,353.00
Advertising Sales	123,994.54	128,721.20
Miscellaneous Sales	10,062.86	17,465.67
	$229,778.90	$235,009.87
Additional income was received in the form of		
Contributions	7,500.00	8,000.00
Interest	5,567.21	5,052.07
Making a **Total Income** of	$242,846.11	$248,061.94

	1921	1922
Expenditures for the year ended Sept. 30 were	$233,115.01	$263,389.77
For the following purposes		
Publications	51,425.33	46,012.38
Standards	27,960.60	29,275.00
Meetings	10,379.17	10,024.01
Membership Increase	8,614.79	7,483.88
Sections	10,630.48	9,561.06
Research	1,004.98	15,281.96
Employment Service	1,324.77	3,530.96
Cost of Advertising Sales	23,209.19	34,650.14
Cost of Miscellaneous Sales	6,881.31	10,660.21
General Administration	91,684.39	96,910.17
Total Expense was	$233,115.01	$263,389.77
leaving **Unexpended Income** for the fiscal year	9,731.10	
Deficit		15,327.83
On Sept. 30, 1922, the Society had Government and railroad bonds of	Par Value	$78,000.00
	Market Value	76,185.30
	Purchase Value	76,513.13
and accrued interest of		2,284.04

ESTIMATED BUDGET FOR 1923

Income	
Dues and Subscriptions	$75,000.00
Contributions	7,500.00
Interest	5,000.00
Initiations	13,200.00
Advertising Sales	154,779.25
Miscellaneous Sales	13,106.00
Expense	
Publications	$58,250.00
Sections	10,450.00
Research	19,000.00
Employment Service	4,050.00
Standards	27,450.00
Cost of Membership Increase	10,000.00
Cost of Advertising Sales	40,850.00
Cost of Miscellaneous Sales	8,740.25
Meetings—Net Cost	10,825.00
General Expense	78,970.00
	$268,585.25 $268,585.25

It is the wish and endeavor of the officers of the Society to reduce the expenses so far as is in keeping with the Society's best interests, in the hope of showing at least a small amount of income in excess of expenditures.

RESALE VALUE

THE determining factor in the automobile business is based upon the word "service" and is exemplified in resale value. The thing that will determine ultimate production is not the original list-price but the second-hand price. There are 88 member companies in the National Automobile Chamber of Commerce. Twelve of them build about 87 per cent of the cars the 88 companies produce. Not all of the products of those 12 have a high second-hand value. I asked about 500 leading distributors to tell me the second-hand value of the last three models of the 30 leading producers in the industry. I found that they maintain a list of 12 to 15 automobiles which they consider to be of sufficiently high second-hand value to take them in with the hope of a profit in the second sale.

The dealer is handling about 80 per cent of his business on a time basis. Every time he sells an automobile, he takes in one, two or three other automobiles. He discovers very quickly that there is only one chance for him to stay in the business as a dealer, and that is to find out what cars have sufficient value to enable him to sell them a second time at a profit.

A man who starts in business to do one thing consistently day after day and year after year, and sticks to it, not influenced by this or that dealer or sales manager, or this or that new idea, is likely to dominate his field, because he develops the economic situation from the standpoints of manufacture, distribution and service. The only way to undersell another man is to build a better car.—From remarks of E. S. Jordan before the Detroit Section of the Society.

Testing Fuels for High-Compression Engines

By Stephen M. Lee[1] and Stanwood W. Sparrow[2]

Annual Meeting Paper *Illustrated with* Charts and Drawings

THIS paper is concerned with certain of the methods used and results obtained in two investigations of fuels for high-compression aviation engines. The fuels in question are benzol and ethyl alcohol, either alone or as blended with gasoline.

The necessity of mixture-ratio runs in fuel investigations is vigorously emphasized. In that the tendencies of a fuel to detonate or preignite limit the conditions under which it may be used, methods of estimating these characteristics are discussed. Also a graphical representation has been made to illustrate the relation between compression pressure, compression-ratio, volumetric efficiency and indicated power in order that, with a given engine, the effect on detonation of changing engine conditions may be estimated.

Results characterizing the performance of the different fuels are mentioned and particular attention is directed to cases where these results are in contrast with current opinion.

TWO investigations, both relating to fuels for use in high-compression aircraft engines, are being conducted by the Bureau of Standards. These differ only in scope; the one authorized by the Bureau of Aeronautics of the Navy Department is primarily concerned with certain specified fuels, while that authorized by the National Advisory Committee for Aeronautics is without such specifications. This paper deals with such of the methods used and results obtained as are believed to be of interest to the members of this Society.

The majority of aircraft engines are now employing as high a compression-ratio as will permit safe operation with aviation gasoline. It has long been appreciated that increased power and economy could be obtained if a higher compression-ratio could be used satisfactorily. Hence arises the interest in fuels whose tendency to detonate is less than that of gasoline and which therefore will permit the use of higher ratios. Among such fuels are benzol and ethyl alcohol, both of which were specified in the investigation authorized by the Bureau of Aeronautics.

Throughout this paper the term compression-ratio is used interchangeably with expansion-ratio because these two ratios are equal in nearly all existing engines although such need not be the case. It should be remembered that it is from the increase in *expansion-ratio* that the increase in power and economy is obtained, while it is the increase in compression pressure resulting from an increase in compression-ratio that necessitates a non-detonating fuel. Although the valve-timing of an engine can be selected so that the effective compression-ratio is less than the expansion-ratio, such an arrangement decreases the power output for a given piston displacement. Consequently this practice has not been generally adopted and, at present, to obtain the advantage of a high expansion-ratio it is necessary to overcome the difficulties accompanying a high compression-ratio.

Any program of fuel investigation should include measurements of the corrosive effect of the fuel on various metals, its freezing-point, its distillation range and its solubility in other fuels with which it may be blended. Discussion in this report, however, is limited to the results of engine tests. These tests were chiefly concerned with the power and fuel-consumption obtainable at various compression-ratios with the different fuel blends. In addition, since the tendencies of a fuel to detonate or preignite determine how high a ratio may be satisfactorily used, every effort was made to estimate these tendencies.

Methods of Test

Much the greater portion of the work was done with a one-cylinder Liberty engine. While the performance of a one-cylinder engine is not identical with that of one cylinder of a multi-cylinder engine of the same dimensions, yet the results obtained form a satisfactory basis for predicting the performance of a multi-cylinder engine with various fuels or various ratios. To interpret the power measurements properly requires that comparisons be made on the basis of the indicated, or the sum of the brake and the friction, horsepower because of the proportionately higher friction-loss of a single-cylinder engine. However, specific fuel-consumption results even upon an indicated-horsepower basis are not applicable directly to multi-cylinder engines. It is probably possible to get lower specific fuel-consumption with a single-cylinder engine than with a multi-cylinder engine because of the absence of the distribution problem. However, on account of pulsations in the intake system the specific fuel-consumption is usually higher, as was the case in this investigation. These pulsations have another disturbing influence on the engine performance in that they cause wide variations in the volumetric efficiency with change in the engine speed. Since both the power developed and the tendency to detonate vary directly with the volumetric efficiency, it can be easily appreciated why care must be exercised in using results obtained with a single-cylinder engine to foretell the performance of a multi-cylinder engine.

It is the practice in this laboratory whenever possible to maintain a constant air-temperature at the entrance to the carbureter. This is accomplished by heating the air to a temperature a few degrees higher than the highest temperature likely to be found in the laboratory. There is ample evidence that, at a constant air-temperature, indicated power varies directly as the absolute or barometric pressure of the air at the entrance to the carbureter. Power measurements can therefore be corrected to a standard barometric pressure on this basis. For careful measurements of detonation it would be desirable to keep this pressure constant and equal to standard atmospheric pressure. All power measurements in

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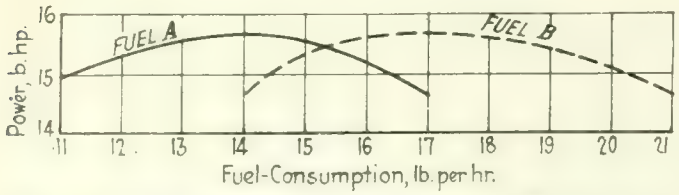

FIG. 1—CURVES SHOWING HOW THE SAME MAXIMUM POWER CAN BE OBTAINED FROM TWO DIFFERENT FUELS BUT NOT WITH THE SAME AMOUNT OF EACH FUEL

these tests were made with an air temperature of 86 deg. fahr. and have been corrected to a barometer reading of 29.9 in. of mercury.

In engine tests of this kind it is necessary that runs be made at many carbureter settings differing by small amounts to determine the relation between, and values of, the power and the specific fuel-consumption for each of the fuels or blends. Such runs were first made with what appeared to be the best spark-advance. To make certain that "appearances were not deceiving," and also

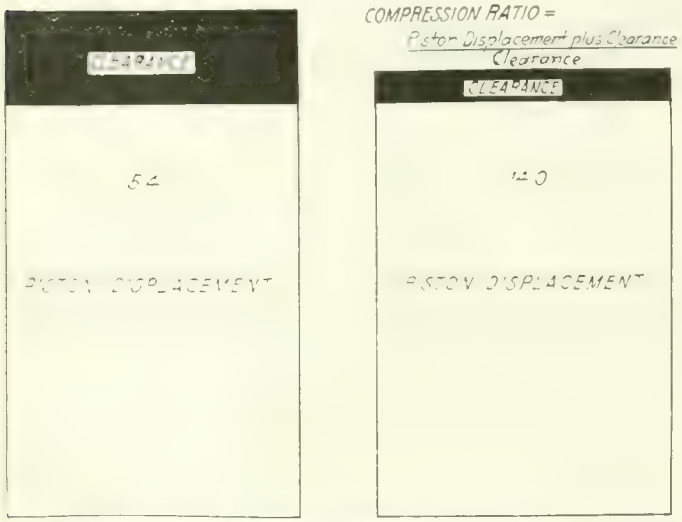

FIG. 2—COMPARISON OF THE COMPRESSION-RATIOS USED IN MAKING THE TESTS

to observe the effect of the spark-advance on detonation, it was customary to make other runs at greater and less advances. The question naturally arises as to whether a single adjustment of the mixture-ratio and the spark-advance would not be sufficient for comparisons of the power, since the power may remain sensibly constant while either the mixture-ratio or the spark-advance is varied a considerable amount. It is true that insofar as determinations of the maximum power are concerned mixture-ratio runs although desirable are not essential. Nevertheless they serve as valuable evidence that correct adjustments were made. However, in fuel-consumption comparisons it is absolutely necessary to make mixture-ratio runs. In some of these tests there was a variation of over 20 per cent in specific fuel-consumption with but 1-per cent variation in the amount of power developed. How uncertain a comparison based on single maximum-power readings would be is easily appreciated. Fig. 1 emphasizes the necessity for mixture-ratio runs in comparing fuels. As will be observed the same maximum-power is obtained with each fuel but not with the same *amount* of each fuel. For example, with a fuel-consumption of 14 lb. per hr., which gives the maximum power for fuel *A*, the engine develops 15.7 b. hp. with fuel *A* or 14.6 b. hp. with fuel *B;* while with a fuel-consumption of 17 lb. per hr. at which the maximum power is obtained from fuel *B*, the engine develops 14.6 b. hp. with fuel *A* or 15.7 h. hp. with fuel *B;* hence a maximum-power setting of either fuel gives a comparison that is unjust to the other fuel. With a carbureter adjustment giving between 11.0 and 15.3 lb. of fuel per hr. more power would be developed with *A* fuel than with *B*. If the adjustment gave a flow of between 15.3 and 21.0 lb. of fuel per hr. the reverse would be true. This sort of condition is likely to result when fuel comparisons are made using fixed sizes of carbureter jet and it is easy to understand why the results of fuel comparisons by different experimenters so often disagree.

It should be noted that accurate measurements of the mixture-ratio are not essential to obtain the benefits of mixture-ratio runs. The results of these and many other engine tests have shown that the quantity of air entering the engine per cycle does not vary appreciably with changes in the mixture-ratio. Hence, for a given engine speed and throttle opening, a curve of power versus fuel-consumption is essentially power versus mixture-ratio, even though the actual mixture-ratio is unknown. This is particularly fortunate, for, while accurate measurements of the fuel-consumption are easily obtained, the situation is very different with regard to measurements of air.

In this work detonation was estimated by sound, by the decrease in power, by the increase in jacket loss and by the destruction of diaphragms so mounted in a spark-plug shell as to constitute an uncooled portion of the combustion-chamber wall.[3] Considerable confidence was placed in the last-named measurement, since it is a gage of the destructive effect of detonation, which phase of the problem is of major importance in aviation work.

Preignition, while easy to recognize, is difficult to measure even comparatively. Mr. Ricardo, in his report on the Influence of Various Fuels on Engine Performance[4], gives self-ignition temperature values for various fuels as determined by conventional methods at atmospheric pressure[5] and by adiabatic compression with air.[6] By the former method the self-ignition temperature of benzol was found to be higher than that of ethyl alcohol, while by the latter method it was found to be lower Which value should be used? Neither method completely simulates engine conditions. This will be evident from what follows. During the compression stroke of an engine there is an increase in the gas temperature due to the heat of compression and a further increase in the temperature of certain portions of the charge caused by the communication of heat from local hot-spots in the combustion-chamber. If the total heat input is sufficient to ignite the charge, the engine will continue to fire when the ignition circuit is broken. So long as ignition by this means does not precede the electric ignition it is unobjectionable. It usually happens, however, that this phenomenon occurs earlier and earlier with each successive stroke until the power delivered by the preigniting cylinder becomes nil. In the case of a multi-cylinder engine one or more cylinders may go into preignition and yet the remaining ones deliver sufficient power to keep the engine running. Upon examination the pistons, valves and spark-plugs in such cylinders will show indications of having been unusually hot. A reasonably satisfactory method for comparing preignition in actual engines is to compare the operation with several spark-

[3] See National Advisory Committee for Aeronautics Technical Note No. 101.
[4] See *Automotive Industries*, May 12, 1921, p. 1003.
[5] See *Automobile Engineer*, May, 1920, p. 199.
[6] See *Automotive Industries*, May 12, 1921, p. 1004.

plugs whose relative tendency to preignite is fairly well known. Suppose that with one fuel a plug that is known to cause preignition readily is used without trouble and with another fuel serious preignition occurs even with a spark-plug that is known to be comparatively free from tendencies to preignition. This is good evidence that the latter fuel is more prone to preignition. Much the same sort of a comparison can be made by noting the difference in the spark-advance that is necessary to produce preignition with different fuels in the same engine. Another method is under development which it is hoped will provide more satisfactory and definite means of measuring these tendencies.

Results

The problem of fuels and compression-ratios can be approached from at least two points of view. One may attempt to select the best fuel-blend for a given compression-ratio or the best compression-ratio for a given fuel-blend. It is along the latter line of endeavor that the most effort has been expended, both in this and in other investigations. The range of compression-ratios studied is indicated in Fig. 2, which shows the volumes before and after compression for the lowest and highest ratios investigated. Results obtained with these and intermediate ratios when using gasoline, benzol and mixtures of the two are summarized in Fig. 3. It is evident that there is an increase in the power and a decrease in the specific fuel-consumption with each increase in the

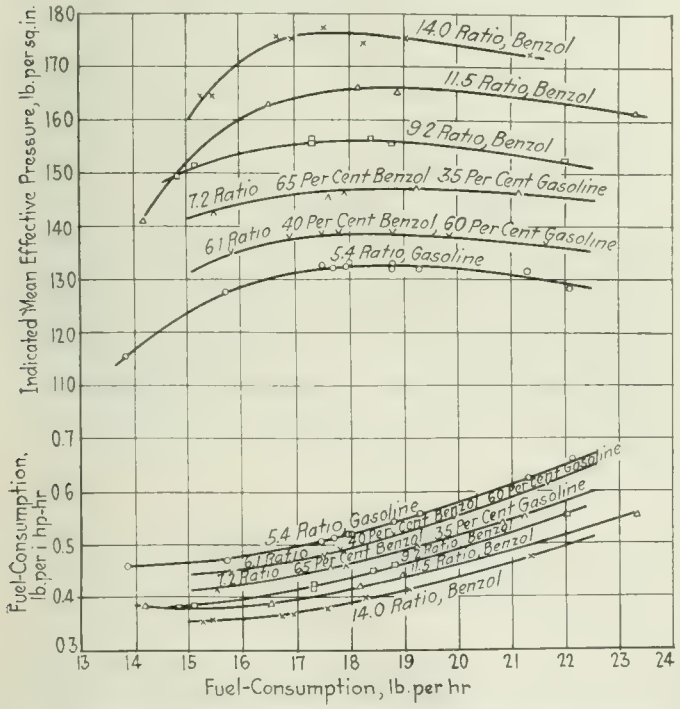
Indicated Mean Effective Pressure, lb. per sq. in.
14.0 Ratio, Benzol
11.5 Ratio, Benzol
9.2 Ratio, Benzol
7.2 Ratio 65 Per Cent Benzol 35 Per Cent Gasoline
6.1 Ratio 40 Per Cent Benzol, 60 Per Cent Gasoline
5.4 Ratio, Gasoline
Fuel-Consumption, lb. per i.hp-hr
Fuel-Consumption, lb. per hr

Fig. 3—Power and Fuel-Consumption Curves for Different Fuels and Compression-Ratios Obtained from a Single-Cylinder 5 x 7-In. Liberty Engine at a Speed of 1500 R.P.M.

ratio. Since the maximum power is obtained with approximately the same quantity of fuel in each case, it follows that the increase in the power at the higher ratios is not obtained at the cost of a rich mixture acting as an internal cooling medium. The data shown in this figure form the basis for the dotted curve of Fig. 4. The full-line curve of this figure shows the theoretical increase in the power and the efficiency as calculated from the air-cycle efficiency, using the lowest ratio, 5.4, as the basis of comparison. Circles represent actual experimental determinations and it should be noted how close to the theoretical curve they fall. It is interesting to observe how closely the theoretical increase in the power

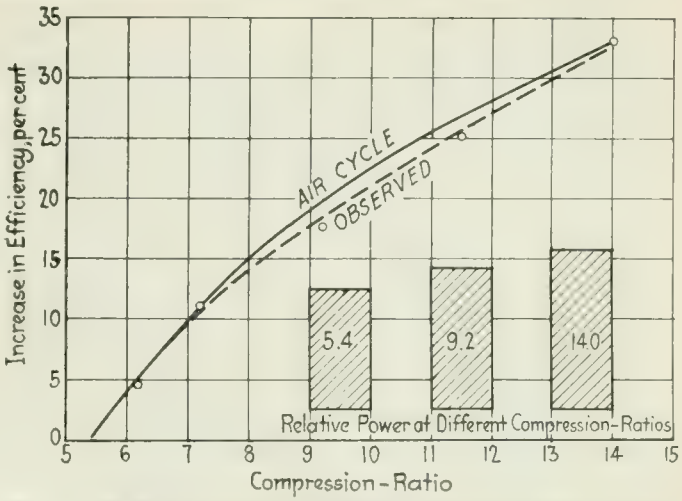

Fig. 4—How the Efficiency Increases with an Increase in the Compression-Ratio

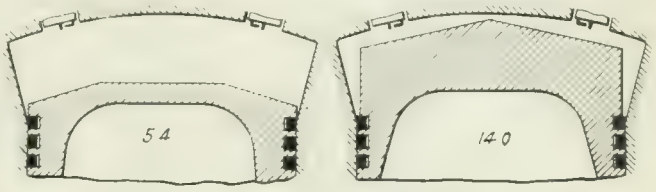

Fig. 5—Combustion-Chamber Shapes Used in the Tests

was approximated even with a combustion-chamber of the shape shown in Fig. 5. Needless to say, this shape was the result of necessity, not choice.

In Fig. 6 is shown the maximum indicated mean effective pressure obtained with each of the various ratios at an engine speed of 1500 r.p.m. The highest indicated

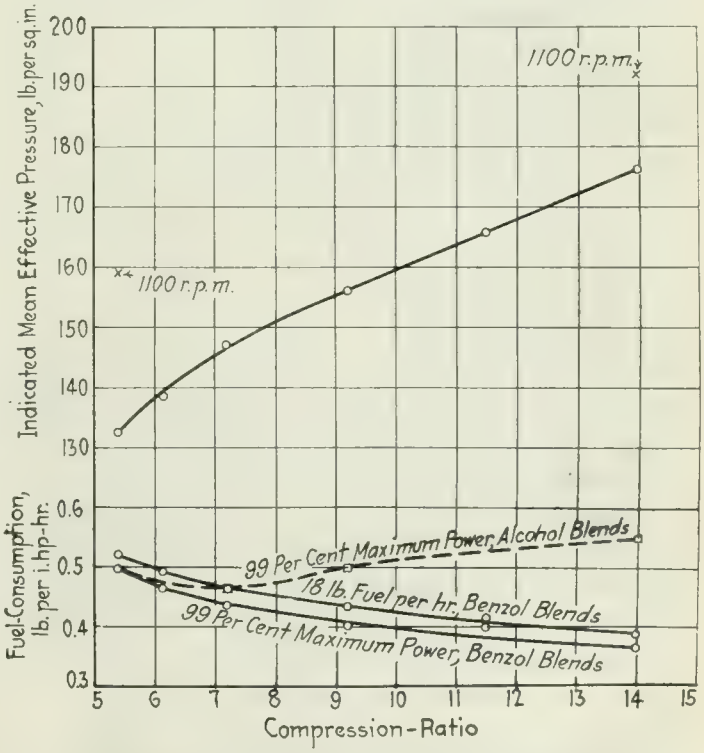
Indicated Mean Effective Pressure, lb. per sq. in.
1100 r.p.m.
1100 r.p.m.
99 Per Cent Maximum Power, Alcohol Blends
18 lb. Fuel per hr, Benzol Blends
99 Per Cent Maximum Power, Benzol Blends
Fuel-Consumption, lb. per i.hp-hr.
Compression-Ratio

Fig. 6—Curves Showing the Effect of Changing the Compression-Ratio on the Power and the Fuel-Consumption

mean effective pressure, 176 lb. per sq. in., was obtained at the 14 ratio. As some engines operate with volumetric efficiencies somewhat higher than that of this engine at 1500 r.p.m., it was thought desirable to make a few measurements at the higher volumetric efficiency that exists in this engine at 1100 r.p.m. Such measurements at a 14 ratio yielded an indicated mean effective pressure of 192 lb. per sq. in. With a mechanical efficiency of 90 per cent, an average value for aviation engines, the corresponding brake mean effective pressure would be 173 lb. In actual practice the mechanical efficiency and hence the brake mean effective pressure would undoubtedly be still higher, as the friction horsepower would not be expected to increase materially with an increase in the compression-ratio.

The upper full-line curve in the lower part of this figure shows the specific fuel-consumption at an hourly consumption of 18 lb., the mixture giving the maximum power in the majority of cases. The lower line shows the specific fuel-consumption at mixtures sufficiently lean to give 99 per cent of the maximum power. This value of 99 per cent is arbitrarily chosen as representing the best economy obtainable with practically full power development. Moreover, a comparison of the fuel-consumption results on the basis of 99 per cent of maximum power has the added advantage that this point is more definite as regards the fuel-consumption than the maximum-power point. The curve of specific fuel-consumption at 99 per cent of the maximum power shows the same tendency as the full-power curve, namely, a continuous decrease with an increase of the compression-ratio up to and including the highest ratio used in this test.

Very different characteristics are shown in the dotted curve of Fig. 6, which is the result of using at each compression-ratio a blend of gasoline and just sufficient alcohol to prevent serious detonation. With the alcohol blends, as with the benzol blends, there was an increase in the power with an increase in the compression-ratio. However, because of the lower calorific value of alcohol, as the necessary percentage of alcohol in the blend increased the weight of fuel required for a given power development also increased until eventually a point was reached where no further increase in economy resulted from increasing the compression-ratio. Recognizing this limitation, it is evident that the selection of an alcohol blend and compression-ratio will be governed by the kind of service to which the powerplant is to be devoted. In short flights the weight of the powerplant and the fuel is chiefly dependent upon the weight per horsepower of the engine. On long flights the fuel-consumption per horsepower-hour is of major importance.

In determining the percentage of benzol or alcohol necessary with each of the various compression-ratios, the criterion was that the detonation and consequently the maximum pressures should not exceed those resulting from the use of aviation gasoline at the standard 5.4 compression-ratio with the spark-advance and the mixture adjusted for the maximum power. It is significant that, when using a suitable fuel at a compression-ratio of 14, the maximum pressures as verified by diaphragm tests were no greater than those resulting from the detonation ordinarily present with a 5.4 ratio under normal service conditions. Mean pressures at the higher ratios are, of course, much greater.

The actual proportions of benzol and gasoline found necessary with this engine are given in Table 1.

[7] See THE JOURNAL, May, 1922, p. 305, and June, 1922, p. 451; also National Advisory Committee for Aeronautics Technical Note No. 93.

TABLE 1—MIXTURES USED WITH DIFFERENT COMPRESSION-RATIOS

Compression-Ratio	Per Cent by Volume Benzol	Gasoline
5.4	0	100
6.1	30	70
7.2	65	35
9.2	85	15
[a]11.5	100	0
14.0	100	0

[a] Although 100 per cent of benzol was used in the tests at this ratio, undoubtedly a blend containing a very small quantity of gasoline would have been satisfactory.

In using alcohol as an anti-detonation agent, it was found to be approximately twice as effective as benzol at the low compression-ratios where the greater portion of the fuel blend was gasoline. At the higher ratios where the gasoline was the lesser constituent there seemed to be little difference between the effect of benzol and that of alcohol. More experiments are needed to determine whether this is a general relationship or the result of a peculiar combination of circumstances. In this connection the two consequences of adding a considerable proportion of benzol or alcohol to gasoline should be appreciated: (*a*) detonation is decreased because the amount of the detonating substance, gasoline, is decreased, and (*b*) detonation is decreased because the amount of the anti-detonation agent is increased. "Dopes" that are effective in relatively small quantities attain their ends in the last mentioned way.

Undoubtedly some investigators will question the proportions of benzol and gasoline cited above. Their own experience may have shown a need for higher percentages of benzol at certain of these ratios. Statements as to the proportion of any anti-detonation agent necessary for engines of a given compression-ratio are misleading because there is ample evidence that the compression *pressure* rather than the compression-*ratio* forms the most reliable gage of the engine's tendency to detonate and hence of its fuel requirements.[7] It follows that the compression pressure and hence the detonation tendencies of an engine of low compression-ratio and high volumetric efficiency may equal or exceed those of an engine of high compression-ratio and low volumetric efficiency. The influence of volumetric efficiency can be understood from consideration of the factors determining the compression pressure. In general,

$$P_2 = P_1 r^n$$

where

n = 1.25 to 1.40
P_1 = the absolute pressure at the beginning of compression
P_2 = the absolute pressure at the end of compression
r = the compression-ratio

It will be seen that a change in volumetric efficiency or barometric pressure by changing P_1 will change the compression pressure P_2 and that the actual amount of this change will increase with an increase in the compression-ratio.

Fig. 7 has been plotted as a sort of birds-eye view of the possibilities open to the engineer in designing an engine to use fuel of known detonation characteristics. It gives the relation between the compression-ratio, the volumetric efficiency, the indicated mean effective pressure and the compression pressure. In the upper portion of the figure a series of compression-pressure curves has been plotted against the volumetric efficiency. These curves were plotted from the relation mentioned above, assuming P_1 to equal 14.7 lb. per sq. in. at 100 per cent

volumetric efficiency and for lower efficiencies to be lower in direct proportion to the efficiency. In securing the lower group of curves the first step was the plotting of an actual measurement of the indicated mean effective pressure obtained at a 5.4 ratio against an actual measurement of the volumetric efficiency. From this point the curves were derived by making two well justified assumptions: (*a*) that at any compression-ratio the indicated mean effective pressure is directly proportional to the volumetric efficiency, and (*b*) that at any volumetric efficiency the indicated mean effective pressure is proportional to the air-cycle efficiency as determined by the compression-ratio.

An example will show best how these curves may be used. Assume a fuel and an engine design such that with an absolute compression-pressure of 160 lb. per sq. in. there is an adequate margin of safety against detonation. From the upper curves it is seen that a pressure of 160 lb. per sq. in. would be obtained with a volumetric efficiency of 71.5 per cent at a compression-ratio of 7 and with a volumetric efficiency of 89 per cent at a compression ratio of 6. The lower curves show an indicated mean effective pressure of 125 lb. per sq. in. to be developed with a volumetric efficiency of 71.5 per cent at a compression-ratio of 7, while an indicated mean effective pressure of 147 lb. is obtained with 89-per cent volumetric efficiency at a ratio of 6. For the 7 ratio the air-cycle efficiency is 54.1 per cent; and for the 6 ratio, 51.1 per cent. Hence, with the lower ratio the indicated power would be 17.5 per cent greater with an efficiency, on the basis of indicated power, 5.8 per cent less.

[8] See *Automotive Industries*, May 12, 1921, p. 1006; also National Advisory Committee for Aeronautics Technical Note No. 93, p. 7.

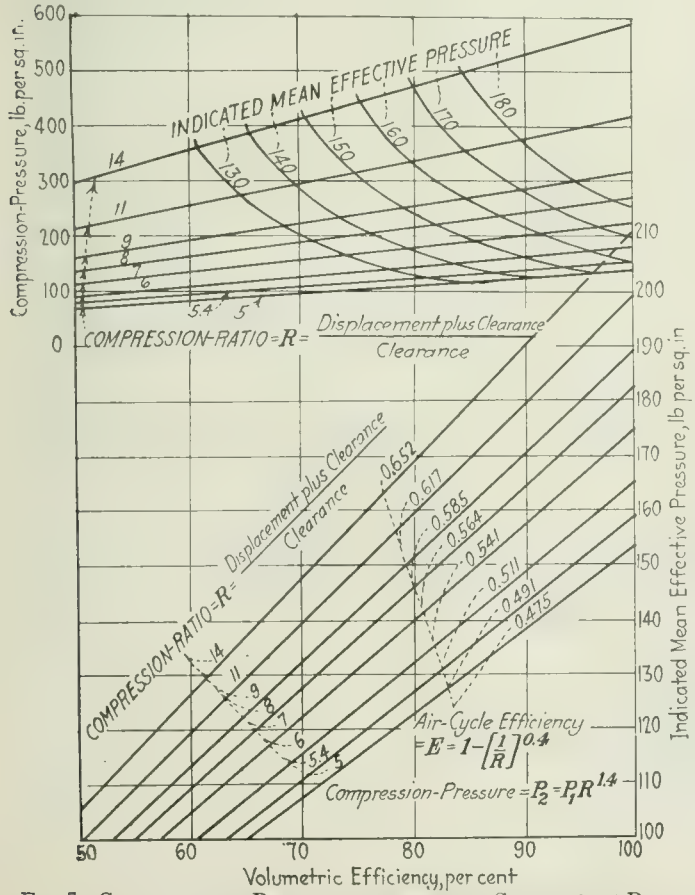
Compression-Pressure, lb. per sq. in.
INDICATED MEAN EFFECTIVE PRESSURE
COMPRESSION-RATIO=R= Displacement plus Clearance / Clearance
Displacement plus Clearance / Clearance
COMPRESSION-RATIO=R=
Air-Cycle Efficiency =E=1-[1/R]^0.4
Compression-Pressure=P2=P1R^1.4
Indicated Mean Effective Pressure, lb. per sq. in.
Volumetric Efficiency, per cent

FIG. 7—CURVES OF THE RELATION BETWEEN THE COMPRESSION-RATIO, THE VOLUMETRIC EFFICIENCY, THE INDICATED MEAN EFFECTIVE AND THE COMPRESSION PRESSURES

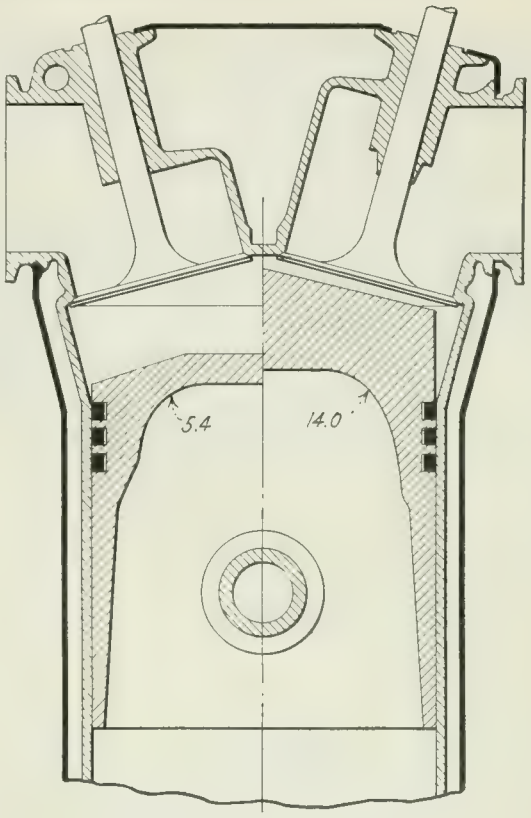

FIG. 8—A COMPARISON OF THE 5.4 AND 14 COMPRESSION-RATIO PISTONS

The engineer who has been confronted with problems of this nature realizes that these curves tell only a part of the story. The engine with the lower volumetric efficiency would need to be larger and heavier to develop the same power. Its mechanical efficiency probably would be low because of its low power per cubic inch of piston displacement. Hence, the difference in brake horsepower for the conditions mentioned would be even greater than the difference in indicated power, while the advantages of the higher ratio from a thermal efficiency standpoint would be somewhat offset by the increased weight per horsepower and the decreased mechanical efficiency. From the foregoing it should not be inferred that the compression-ratio and the volumetric efficiency are the only conditions governing detonation. The size and shape of the combustion-chamber, the location and number of spark-plugs, the cylinder and piston construction all have influences which can be determined only by experiment. Moreover, in maintaining a constant margin of safety from detonation, the permissible compression-pressure does increase slightly with an increase in the compression-ratio. This results from a slight decrease in the ratio of the explosion pressure to the compression pressure.[8]

In spite of these many qualifications this plot, Fig. 7, does make clear why with a given fuel an engine of high volumetric efficiency is limited to a lower ratio than one of lower volumetric efficiency. It shows also that, so long as detonation is the limiting factor, the greatest power output with a given fuel and engine may be obtained by first securing the highest possible volumetric efficiency and then employing the highest compression-ratio that will provide adequate safety from detonation.

In some instances preignition rather than detonation may be the factor that determines the proportions of the blended fuel. This may be the case with alcohol-gasoline blends, for, although alcohol seems to possess more anti-

detonation effect than benzol, it appears to be more prone to preignition. With the engine used in these experiments there was an increased tendency to preignition with an increase in the compression-ratio but the amount of this increase was less than had been expected. In fact, the spark-plugs used throughout these tests were of a type commonly used in aviation engines for the past 4 years. Although in no respect special they gave no trouble even at the 14 ratio. The explanation is not difficult when the factors influencing preignition, mentioned earlier in this paper, are understood. As there stated, preignition depends upon (*a*) the heat of compression, and (*b*) the heat supplied to the charge by local hot-spots in the cylinder. The first is increased by an increase in the compression-ratio; the second is probably decreased. The change in the heat of compression can be estimated from the relation

where

$$T_2 = T_1 r^{n-1}$$

n = 1.25 to 1.40
r = the compression-ratio
T_1 = the absolute temperature at the beginning of compression
T_2 = the absolute temperature at the end of compression

How much heat is supplied to the charge by local hot-spots depends very largely upon the piston and cylinder design. That this will decrease with an increase in the ratio could be shown by comparative plots, based upon theoretical considerations, of the change of temperatures throughout the cycle. A familiar, though perhaps unappreciated, illustration of this same effect is the common expedient of retarding the spark to make an engine heat-up quickly. Obviously, the increased heat is the result of the decreased expansion of the gases after burning. These observations make it clear that engines may require different fuel-blends solely because differences in design give them unequal tendencies to cause preignition. Differences in the tendency toward preignition with different compression-ratios may be less than the difference in the tendency toward preignition of different engines at the same ratio. Therefore, one must be cautious in using test-engine results as a basis for selecting fuels for other engines.

Perhaps undue interest attaches to some of the experimental results because of the degree in which they prove or disprove prevalent opinions. For example, there seems to be widespread belief that alcohol and benzol require a greater spark-advance than gasoline requires. To determine whether there is justification for this belief, runs were made with various spark-advances with each of the three fuels at a compression-ratio and a throttle-opening such that no detonation was present with any of the fuels. However, the maximum power was obtained with the same spark-advance with each fuel. It seems probable that whenever the best spark-advance for alcohol or benzol has been found to be greater than that for gasoline, this fact can be considered an indication that detonation was present when gasoline was used and that for this reason the spark-advance was not used which, in the absence of detonation, would have given the maximum power.

A similar situation exists with regard to the jacket loss, an important item in aviation work since it determines the size of radiator necessary. Some investigators have found a marked decrease in the jacket loss upon changing from gasoline to alcohol. No such effect, however, was found either in these experiments or in experiments with multi-cylinder engines in the altitude chamber. Again the difference probably can be charged to detonation or preignition, whose presence when using gasoline as a fuel caused unusually high jacket-losses which disappeared when these conditions were eliminated by the use of alcohol or benzol.

Another illustration is available of the influence that engine characteristics may have on work of this kind. It will be remembered that with benzol some experimenters have encountered preignition without audible detonation at ratios of less than 8. This might lead one to suppose that some quality of the fuel made detonation impossible. That such is not the case was shown by these experiments, for both alcohol and benzol detonated at the 14 ratio, provided the spark was advanced sufficiently.

To obtain within a reasonable time a piston that would give a 14 compression-ratio the rather crude expedient of welding additional metal to the head of a 7.2-ratio piston was adopted. As shown in Fig. 8, the result was an abnormally thick piston-head. This thick head may have been a real advantage in that it provided a large mass of metal capable of rapidly absorbing heat during the period of combustion when the gas temperatures were extremely high.

The necessity of a proper combustion-chamber shape has been stressed so much that added interest attaches to the fact that very nearly the theoretical power-increase was attained with the unconventional shape shown in Fig. 5. This does not imply that this shape, necessitated by the flared cylinder construction, is desirable, or that it might not give very poor performance at reduced throttle. Even with this shape, however, less spark-advance was necessary than at the lower ratios. Maximum power at the 5.4 ratio was obtained with an advance of 26 deg., while with the 14 ratio a 13-deg. advance was sufficient.

It is axiomatic that knowledge of the possibilities of operation under a certain set of conditions must precede any estimate as to the desirability of operating under such conditions. The sole effort of this paper has been to outline some of the possibilities in the use of high compression and to call attention to some items of interest that have appeared in this explorational investigation.

Automotive Work as a "Profession"

By Dr. C. A. Prosser[1]

Minneapolis Section Paper

THE author outlines what constitutes a "profession" and discusses the factors necessary in the making of a real profession of automotive work. The essentials are stated to be a body of knowledge built up through experience for use as a guide; its collation and organization so that it can be taught to others; the establishment of training schools; recognition by society in general of the social benefit of a profession and consequent financial assistance; the development of a professional consciousness on the part of individuals engaged in the same lines of effort; and a vision, on the part of the individuals engaged in a given line of work, of the social service that they do by the proper pursuit of their own calling.

NO industry in the history of the world has grown so rapidly as that of automotive production. The value of the mechanisms handled, the problems involved in the standardizing of parts, the necessity in the stress of competition for constant improvement in the product and the many applications of scientific principles that the automobile requires, have made necessary the employment of large numbers of technicians and engineers. This technical service concerns itself at the factory with experiments and improvements in the manufacture of the automobile itself. At distributing points throughout the Country, it is more and more concerned with the many problems involved in the repair and sales end of the industry. These problems range all the way from the better organization and administration of the plant and the office to advancements in the processes of repair.

The men who come into this work locally range all the way from graduates in mechanical and electrical courses of engineering colleges, particularly the former, to men who have grown up in the business. They largely combine with a general education and reading a wide experience either in the repair or the sales end of the business. What I have to say has to do with the opportunity and necessity of the local automotive engineer making a real profession of his business.

There are certain earmarks of any work in the world that raise it to the opportunity, spirit and dignity of a profession. I will set them up one by one as a straightedge and point out the extent to which the work in the automotive industry conforms to the same tests.

What Constitutes a "Profession"?

We never have a "profession" until a body of knowledge is built up through experience to guide those who are engaged in its pursuit. This is true of law, medicine, education and all forms of engineering. While the automobile has been in existence only a comparatively short time, science and experience, working together, have built up a rich body of knowledge that a man must have if he is to become a professional servant and leader in the business.

Until this body of knowledge is collated and organized so that it can be taught to others, it does not constitute the basis of a profession. Special courses in automotive and tractor engineering and other practical courses are being established in industrial and trade schools everywhere for the conferring of the knowledge that is being organized into textbook material and published broadcast.

In the truest sense of the word, we do not have a profession until schools are established for training persons who are to pursue it. This step already has been taken. Preparation for the profession of the automotive engineer will, in my opinion, come through the engineering school, where special courses will be established for those who intend to specialize in automotive engineering; through the industrial and trade-school courses, particularly in part-time and evening work; and through correspondence-school courses and related reading on the part of the ambitious man in the trade who has successful experience and seeks to improve his professional standing.

A profession does not amount to much until society comes to recognize the social benefit of the profession and establishes, at public expense, means whereby persons can become better trained for its successful pursuit. As in every other line, history has repeated itself in the case of training for automotive and tractor service. The work begun with private schools is now being taken over rapidly by the public as the social worth of the service becomes recognized.

Professional Consciousness

Until those who are engaged in a given line of work come to develop a professional consciousness, their work is not a profession. This has been true in law, in medicine, in education, in theology and in all the forms of engineering. A man develops a professional consciousness when he comes to have a deep sense of interest and pride in his calling; when he is an earnest student of his line of work; when he is sensitive to the difficulties and weaknesses of his own service and that of his fellows; when he throws himself, heart and soul, into his task, not only improving his own efficiency but advancing the interests of the profession in which he is enlisted.

The professional consciousness must rise to a point such that those engaged in the work associate themselves in local, state or national societies in the interest of their business, whatever it may be, before a profession is constituted. In fact, the man who does not belong to the organized associations in his own line may, in most cases, be rated as one of the less desirable members of his profession.

The professional consciousness of a group of men develops a professional code of ethics or conduct in the relationship of these men with each other, before any line of work becomes a profession. Members need to be, and usually are, jealous of the reputation of the group. They gradually come to establish standards of professional conduct in the performance of work. They do not want the inefficient or the dishonest man to be associated with them; whenever they can, they proceed to drive them out of the business. They work for recognized legal or trade standards of preparation to which they wish those who enter the business or who become associated with them in a society to conform.

As this professional consciousness increases, members

[1] Director, the William Hood Dunwoody Industrial Institute, Minneapolis.

of a group came to have a code of conduct in their relationship with each other. Some of the items in this code of conduct are friendliness with each other in spite of competition, fairness in their dealings with each other, the absence of personal criticism, denunciation and innuendo, and a bond of brotherhood in a common cause. I believe this result will come about in automotive engineering through the association of the members of the Society and with the growth of its professional spirit that is sure to come with the development of the automobile business, the deepening of individual experience and the strengthening of the relationships of the members with each other.

Social Worth and Service

To constitute a profession in the truest sense, those engaged in it must come to have a vision of the social worth and service that they are performing through the proper pursuit of their own calling. One very strong illustration of that at present is the extent to which doctors are giving of themselves in so many ways to clinics, to campaigns for public health, to the fight against disease and to the promotion of preventive measures of all kinds. By the standardizing of their service and the spread of information and procedure, which reduces the amount of sickness and disease, it would seem at first glance as if the doctors were interfering with their own business, because the policy that they are pursuing so earnestly in so many quarters is reducing the number of patients. The doctors have taken the higher ground in this as they have become professionally conscious of the responsibility of their greater knowledge and skill for public well-being. In the end it will all redound to the best benefit of their own profession.

The automotive engineer likewise needs to catch a vision of what efficiency in every phase of the automobile business means to the public in reducing expenditures, in the prevention of accidents, in comfort, in the greater mobility of the human race, in quicker and safer communication and in all the things about the automobile that make it such a marvelous instrument for personal pleasure and social good. Every step that is taken in the improvement of any phase of the automobile makes in this direction, and gives, or should give, the automotive engineer the very great gratification of knowing that the medium by which he makes his living is very much worthwhile socially.

The foregoing is a statement of goals. The preliminary steps have been taken by the Society of Automotive Engineers, and it rests with the local sections of the Society and their individual members whether these ideals shall be realized fully.

DECEMBER COUNCIL MEETING

THE meeting of the Council held on Dec. 5 at New York City was attended by President Bachman, First Vice-President Whitbeck, Second Vice-Presidents Clark, Brautigam and Segner, Councilors Scott and Crane, Past-President Beecroft, Treasurer Whittelsey and A. J. Scaife, nominee for the 1923 Council.

The financial report as of Oct. 31 showed a net balance of assets over liabilities of the Society of $121,806.46, this being $16,039.92 less than the corresponding figure on the same day of 1921. The income of the Society for the first month of the current fiscal year amounted to $21,840.95. The operating expense during the same period was $22,534.30.

One hundred and seven applications for individual membership and 42 for student enrollment were approved. The following transfers in grade of membership were approved: From Associate to Member, O. W. L. Coffin, Herman A. Zeller, R. O. Butterfield, Harvey E. Clay, L. H. Gaylord, H. Borreson, H. G. Prodoehl; Junior to Member, E. L. Apor; Junior to Associate, Emil F. Anderson, M. O. Hodgins, Frank R. Wood, H. Woodall, Scott F. Hunt, Sterling O. Wilson, Tsao Yu.

It was reported that during the month of November 105 applications for individual membership and for student enrollment had been received as compared with 66 applications received during the same month of 1921, and 113 during the same month of 1920. On Nov. 30 there were 5321 names on the rolls of the Society, including affiliate member representatives and enrolled students, as compared with 5246 on the same day of 1921 and 5230 on the same day of 1920.

The following subjects were assigned to various Divisions of the Standards Committee:

Storage Battery Tray Terminals — Electric Vehicle Division
Motorboat Lighting Equipment—Lighting Division
Tail-Lamp Illumination—Lighting Division
Brake Ratchets—Parts and Fittings Division
Flexible Discs—Parts and Fittings Division
Hardwood Lumber—Passenger-Car Body Division
Paints, Varnishes and Enamels—Passenger-Car Body Division
Aluminum Sheets—Passenger-Car Body Division
Footman Loops—Passenger-Car Body Division

Earle Buckingham, E. H. Ehrman and George S. Case were appointed a committee on editorial methods of expressing limits and tolerances in connection with the issuance of data sheets of the Society.

The concluding sessions of the present Council were scheduled for Jan. 8 and 9.

Automotive Transportation by Trailers

By E. R. Greer[1]

Minneapolis Section Paper *Illustrated with* Photograph

THE author states that trailer operation is a highly specialized form of transportation and has features of flexibility that make it of far greater importance than is generally supposed. Certain specified limitations must be adhered to, because of existing laws and regulations, and there are other limitations due to the laws of mechanics and the present state of development of this form of transport.

The legal restrictions in regard to gross weight are enumerated and commented upon, as well as those applying to wheel loads and to front and rear-axle loads. The cost of operation is divided into seven parts that are specified. In regard to passenger transportation, the suggestion is made that semi-trailers with passenger bodies be used, and six advantages to be gained thereby are given.

THE general public and probably many engineers are inclined to look upon trailers as suitable for use only in special cases. Where roads are good and large quantities of any commodity are to be transported, the idea of using a trailer may occur to anyone; but trailer operation is a highly specialized form of transportation and has features of flexibility that make it of far greater importance than one might suppose. Certain set limitations must be adhered to, due to existing laws and regulations, and there are other limitations that result from the laws of mechanics and the present state of development.

We are permitted to have 800 lb. of weight per inch of tire width, 22,500 lb. gross weight on one axle or 28,000 lb. gross weight on one vehicle. We are allowed a speed of 6 to 25 m.p.h., depending on traffic conditions. Vehicles must not be over 8 ft. wide and 80 ft. long, and they must not be too noisy or destructive.

Supposing that the volume of work to be done is large; to arrive at the maximum economy in automotive transport it is necessary, first, to carry the largest possible load each trip; second, to travel as fast as possible; and, third, to reduce the time of loading and unloading to a low minimum.

A certain amount of weight is required to get the traction necessary to move the load, and the weight must be balanced so that all road conditions can be met. There must be enough weight on the steering wheels to provide positive control when a sharp turn must be made on slippery pavements, and when hauling a maximum load up a 10 to 15-per cent grade. The problem is simple, but it is not often given consideration.

Tires 14 in. wide or a total of 28 in. of tire width per axle will carry 22,400 lb. at 800 lb. per in. of tire width. This is the limit; so, it is necessary to use more axles to carry heavier loads. The logical procedure is to use trailers. A consideration of speed and the avoidance of delays will show at once that a single trailer is enough, even if two trailers could be kept within the 80 ft. of allowable length. A consideration of the balance of the load and economy in operation will show that the two-wheel trailer, or semi-trailer, offers the best possibilities. As a result, it appears that whereas the 6-ton truck represents the limit in truck capacity, the 12-ton semi-trailer is the limit in the six-wheel unit. Such a vehicle is shown in Fig. 1.

Fig. 1.—An Application of the Tractor and Semi-Trailer to the Transportation of Merchandise

The 6-ton truck with a 6-ton load weighs about 24,000 lb., with about 20,000 lb. on the rear axle and 4000 lb. in

[1] M.S.A.E.—Vice-President and engineer, Motor Transport Co., Minneapolis, Minn.

front. The 12-ton semi-trailer with a 12-ton load weighs about 28,000 lb., one-third of which is to rest on the truck tractor, that weighs about 7000 lb. The trailer axle carries 18,700 lb.; the rear axle of the tractor, 16,300 lb.; and the front axle, 4000 lb. Hence, the load on the road is lighter in the case of the semi-trailer, although the total net load is doubled.

The 6-ton truck might be hitched to a four-wheel trailer of 6 or even 12-ton capacity, but such a combination is awkward, difficult to operate and expensive. It is a time-waster instead of a time-saver, because the truck itself must be held for loading and unloading, or it could not pull the trailer. It is almost impossible to back up such a trailer. At more than 10 m.p.h. there would be trouble caused by the "snaking" of the trailer, and the wear-and-tear on the truck would be excessive.

The semi-trailer "handles" as a single unit. It can be operated safely at speeds equal to truck speeds. It can be backed and maneuvered in less space than an ordinary truck. It requires less than 2 min. to exchange trailers, thus eliminating all waste of time for loading and unloading. The economy of operation is excellent, and it is a more flexible and adaptable unit for variable loads and conditions. The maximum size of such vehicles has been mentioned, but the same ratio holds good for smaller sizes.

Overloading is general in the case of all trucks; it is a bad practice, but one that is difficult to prevent. When a semi-trailer is overloaded, only one-third of the overload is carried by the tractor; so there is much less chance of trouble from this source.

Cost of Operation

Low cost per unit of work performed is the objective. If all items of cost are considered, the semi-trailer is the most satisfactory in the majority of cases. Costs must include:

(1) General or overhead expense
(2) Driver, helper and compensation insurance
(3) Fuel, lubrication and tires
(4) Maintenance
(5) Overhaul reserve
(6) Substitute vehicle
(7) Fixed costs, consisting of depreciation, interest on investment, garage, insurance, taxes and license

Passenger Transportation

The subject of passenger transportation is receiving considerable attention now and the question is suggested for discussion: Why not use semi-trailers with passenger bodies? They would

(1) Accommodate more passengers
(2) Have a lower center of gravity, be easier to get on and off from and be safer to ride in
(3) Ride easier than four-wheel buses
(4) Be quiet to ride in
(5) Be free from engine and oil odors
(6) Have a cost per seat-mile less than one-half of that of the usual type of bus

THE DISCUSSION

Phil Overman:—Do the regulations Mr. Greer mentioned, governing power, pressure and speed refer to all types of paving in the State, to dirt roads or to concrete paving?

E. R. Greer:—Those are about the only regulations we have in Minnesota now, and they are the regulations now being advocated for a National vehicle law. I believe the Minneapolis city ordinance agrees with them at present; there is no distinction made as to whether it is a city pavement or a country road.

C. S. Moody:—In regard to ordinary hauling with trailer equipment, how is that limited?

Mr. Greer:—We are running 3½-ton trucks and 3½-ton tractors of exactly the same make; they have the same size engines, the same kinds of traction and axles, and the same sizes of gears. In one case we are carrying a 3½-ton load and in the other case we are normally carrying from 10 to 12 tons. A comparison of these units shows an average of about 4½ miles per gal. with the truck, and 4 miles per gal. with the tractor and trailer. In other words, the difference is less than ½ mile per gal. We get an extra ½ mile per gal. when we pull 3½ tons instead of 12 tons and the operating conditions are pretty severe right now. We hauled greater than 12-ton loads of brick to building jobs during our deepest snow and put them in, in a section where nobody had driven before. We would get in and get stuck in the snow; so we had to back out and pull ahead a few times, but none of our drivers got stuck for more than 20 min., even with the 12-ton load.

Mr. Moody:—Have you had more or less trouble with the 3½-ton trucks?

Mr. Greer:—The trucks have been stuck just as often as the tractors with trailers, and they have been just as long in getting into and out of the snow. The point is that the load on the wheels for the size of tires is about the same, and very little more power is required to pull the additional load on the trailer wheels. Of course, the trailer can get cramped around where the trailer wheels do not track with the tractor wheels; so, the trailer wheels might be in a snow bank and the truck wheels out of it. Under such conditions the tractor wheels would spin around idly.

The four-wheel-drive truck advocated now for rail use is a similar trailer proposition. This truck is built into a tractor, and the body that the passengers ride in is a trailer body which is carried partly on a power unit. In the original test, it required eight box-cars to constitute the limit of traction that could be maintained with a steady pull by the truck. On a level track, the dynamometer registered a 3600-lb. pull to start those box-cars into movement. After they were well started a 3000-lb. pull hauled the total load, which was 120 tons. That was on dry rails. When the rails were wet, it was impossible to pull anywhere near so great a load. That truck weighed 6300 lb. and had a 4-ton additional load; so there was somewhat more than a 10,000-lb. weight on the traction wheels.

Mr. Moody:—On this power-trailer proposition it seems to me that this can be confined only to smaller units, unless it is run on rails. By running it on rubber tires, the steering proposition would not only be complicated; it would be necessary to have differentials. These difficulties could be eliminated by running the car on rails, because the car would steer itself; it would not require any steering mechanism or any differentials to be incorporated in its equipment.

Questions Answered by the Research Department

MANY of the inquiries answered by the Research Department are of much general interest and involve a considerable amount of thought and research. For the information of our members a few of them will be published each month. It is hoped that in this way those members who have not yet availed themselves of the facilities offered by the Research Department may be encouraged to take advantage of them in the future.

COAT-FINISHING EXHAUST-MANIFOLDS

THE following inquiry was received from one of our members, a British builder of high-grade automobiles:

> We are experiencing considerable difficulty in obtaining a good, high-class, permanent finish and appearance on the exhaust-manifold of the engines of our cars, and would be pleased if you could supply us with some information on the various methods used by firms in the United States to obtain the high-class finish they do.

A questionnaire based upon this inquiry was sent out to a number of producers of high-grade cars and to a number of enameling companies to whom the car builders referred us for further information. The following extracts from letters received from the automobile companies summarize their views on the question:

> We have found two very satisfactory ways of finishing our exhaust-manifold. One is Parkerizing with a black Bauer-Barff finish of a fairly permanent nature. The other is a vitriolizing process that enamels the exhaust-pipe with a glassy compound of great heat-resisting qualities and effectively prevents rusting.

> The porcelain enamel finish represents the very best obtainable finish that will withstand any amount of heat.

> We wish to emphasize that we have had considerable difficulty with our exhaust-pipes so far as keeping a reasonable finish on them is concerned. We have tried metal coating and all sorts of enamel, but nothing is satisfactory. Lately we have tried fusel oil, which we find gives a nice finish and withstands considerable heat. We have been in the habit of sending out our work to an enameling company which subjects the exhaust-pipes to a treatment similar to that applied to pottery. The coating is first a dull luster and after being subjected to about 1200 deg. fahr. becomes a brilliant glaze. It looks very much like black enamel and maintains its luster very well up to a temperature of about 1400 deg. fahr.

> We have found after considerable investigation that fused enamel similar to that used on the best grade of cooking utensils is the best suited for the permanent coating of exhaust-manifolds. All other finishes are more or less unsatisfactory, and they do not present so good an appearance as the fused enamel.

The enameling companies replied, in part, as follows:

> There are two methods of porcelain enameling. These are known as the dry-coat and the wet-coat processes. It is by the latter that the automobile companies in this country are finishing their manifolds. They are using this process because it gives them a much more durable finish and at a considerable saving. The method employed for finishing is as follows: The casting is first sand-blasted to give it a smooth finish and to remove all dirt or foreign substances; the enamel is then sprayed on in liquid form and allowed to dry thoroughly, after which the manifolds are placed in a furnace at a temperature of about 1300 deg., which fuses the enamel in with the iron and gives the desired porcelain enamel finish.

> We have a special finish for exhaust-manifolds that consists of a high-gloss black coverage applied at a temperature of approximately 1400 deg. which is nearly double that of the exhaust-pipe of an engine in ordinary use. This gives practically a permanent finish.

> The method we follow in enameling exhaust-manifolds is as follows: The manifolds are first rough-ground so that all protruding chaplets, fins, etc., are removed. The manifold is then sand-blasted with flint shot so that it has a silvery white finish. It is essential that all burnt sand be removed from the casting. The casting is then sprayed with a special black manifold-enamel which is allowed to dry for about 3 hr., at the end of which time it is put in a gas-fired muffle furnace. The temperature in the muffle is approximately 1350 deg. fahr. It takes about 10 min. to fuse the enamel onto the iron so that when the manifold is taken from the muffle it has a high gloss. We find it necessary to respray this manifold and fire it again to get a first-class smooth job. After the manifold is sprayed the first time it is necessary to wipe some of the joints where the exhaust from the cylinders enters the manifold, so that when the manifold is put on an engine it can be fitted to the cylinders properly with a gasket.

> We finish exhaust-manifolds made of malleable iron with one or two coats of black vitreous enamel. The process of vitreous enameling that we use is called the wet process. That is to say, the article to be enameled is thoroughly cleaned, first being subjected to a high temperature. Then it is sand-blasted, after which we spray either one or two coats of enamel upon the surface of the article and burn it at a temperature of from 1400 to 1500 deg. fahr. This gives a fine finish which will withstand a temperature of 1500 deg. fahr., but if subjected to a constant temperature above that, it is apt to lose its finish, become dull and possibly blister. Enameled manifolds should not be used on automobile engines that are being tested.

Most of the protective finishes used on exhaust-manifolds proved more or less unsatisfactory until the development of vitreous enamel finish, for cast or tubular exhaust-manifolds, in recent years. This finish appears to have given highly satisfactory results as to both appearance and permanence.

Discussion of Papers at the Detroit Production Meeting

THE discussion of the papers presented at the Production Meeting of the Society held at Detroit, Oct. 26 and 27, is printed herewith. Efforts have been made in every case to have the authors of the various papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members a brief abstract of each paper precedes the discussion with a reference to the issue of THE JOURNAL in which the paper appeared, so that those who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so easily.

EXPERIENCE NOTES FROM A PRODUCTION NOTEBOOK

BY H. J. CRAIN AND J. BRODIE

WHILE investigating the sources and causes of noise in automobiles during an extensive connection with one of the largest automobile companies, the authors recorded their experiences in the shop in the form of notes. Some of these are offered with a view to stimulating the discussion of the subject and with the hope that additional information will be brought out by an exchange of ideas, particularly on the problem of eliminating gear-noises. In many cases they found that noise was caused by failure to allow sufficient clearance for an adequate oil-film. And it was noted frequently that when one noise had been located and silenced another appeared that had not been apparent before. The topics that have been considered include the running-in of brake-bands, engine knocks, oil-pump gear-noise and that of gears in general, the clearances of ball bearings, backlash, and rear-axle bevel-gears.—[Printed in the November, 1922, issue of THE JOURNAL.]

THE DISCUSSION

PRESIDENT B. B. BACHMAN:—I have had a suspicion that has been confirmed again and again, that we all have a fetish for close fitting, that we forget many times that oil and oil films are actual, physical things and require space and that, with bearings that just fit, when there is no clearance space between them even for atmosphere, the possibility of getting lubricants into them is reduced to zero.

H. M. CRANE:—I am very much interested in the introduction of loosely fitted gearbox bearings to produce quiet gears and especially in connection with the use of ball bearings. Has any test been made of ball bearings in which the balls and races are fitted tightly but the outer races are fitted loosely in the housing? I do not know that that would give the same result. It probably would not, but I think that it might give the desired cushioning effect and the same quieting result.

R. F. RUNGE[1]:—Referring to Mr. Crane's question, I do not believe that the same results could be obtained by making a loose fit between the outer ring of the ball bearing and the housing. This form of construction may tend to dampen some of the transmitted noise but would be dangerous, as the tendency would be for the outer ring to creep or spin in the housing. This would cause excessive wear, especially where the housing is made of aluminum.

The chart shown as Fig. 8 in the paper is apparently based upon theoretical calculation and is evidently intended to give only an approximate idea of the comparison between axial or end play and radial looseness. Actual measurement of the end play shows that for a specific amount of radial looseness the end play will be from 25 to 30 per cent greater than the amount indicated in the chart. The determination of the radial looseness by end-play measurements is not at all reliable, as the amount of total movement of one ring as compared with the other depends on the accuracy of the contour of the ball grooves, the radius of the grooves, the amount of pressure applied when the measurement is taken and whether the one ring is moved in a plane parallel to that of the other ring.

Considerable variation can be had in all of these items but it is at the same time possible to hold the radial looseness constant. In all of the variations that are encountered, the one that will have the greatest range will come from varying the pressure applied when the end play is measured. Under a very light load, there is excessive end-play due to the elastic deformation occurring at the point of contact of the balls with the grooves. As a result, we have found that where the amount of end play must be considered, its determination can be made only when a specific end-load in either direction is applied. From this explanation it will be seen that the determination of radial looseness by the amount of end play is not very reliable. We have developed machines that will determine either radial looseness or radial tightness within 0.0001 in.

Another consideration that is not always taken into account is the amount of looseness or tightness remaining in a bearing after it has been mounted. We find, from experiments, that where an inner race has a press fit on the shaft, the ball groove of that race will expand approximately 70 per cent of the amount of the press fit. Therefore, considering that a bearing has a radial looseness of 0.0005 in. and the inner race has a press fit of 0.0010 in., after the bearing is mounted it will be actually tight by 0.0002 in., all of the looseness having been taken out by the press fit and 0.0002 in. of tightness put in. Where it has been predetermined that a certain amount of radial looseness is desirable, it is very important to be sure that the amount of final looseness required has not been interfered with by the mounting of the bearing. As it is not general practice to force the outer ring of the bearing into the housing, it is not so important to consider these same conditions as applying to the outer ring, although in such cases as where the outer ring is

[1] M.S.A.E., Vice-President, S K F Industries, New York City.

forced into the housing, that should be taken into consideration. It should also be kept in mind that where those types of bearing that must be opposed to stabilize the position of the shaft are used, it is practically impossible to maintain radial looseness or to know its magnitude.

A tightly fitted bearing will make more and a different kind of noise than one that is loosely fitted. The tight bearing will also set up a greater noise where inaccuracies in the bearing exist or where foreign matter, such as metallic chips or abrasive matter, is present. The noise in bearings many times is traceable to the presence of foreign matter, and extreme care is taken in the manufacture of the bearings to eliminate this condition and every precaution should be taken by the user to keep the bearings clean in handling or assembling.

Where normal or tightly fitted bearings are used, the gear noise, as well as bearing noises, is very efficiently transmitted to the gearcase or the housing which, in most cases, will magnify the noise. It is a well-known fact that where an oil cushion can be provided, it will dampen out part of the noise and vibration. I believe, however, that in the use of the looser bearing for application to transmissions, as the looseness of the bearing will more freely accommodate misalignment of shafts and their deflection under load, greater flexibility plays a bigger part in noise elimination.

G. E. GODDARD:—In his experiments with this radial play, did Mr. Brodie discover any appreciable difference in the oil-pumping characteristics of the ball bearing? In some of our earlier experiences we noticed that some ball bearings pumped oil in a certain direction. I think the problem was never solved in our own minds. We turned the bearings end-for-end and they pumped in the same direction. We tried bearings of different makes, with different ball separators, and that seemed to make very little difference. Would increasing the rolling clearance affect the oil-pumping of the bearing?

I think it is common practice to use an oil spinner or throw-off ring to prevent the oil going through a bearing, but believe it would be rather interesting to hear from some of the ball-bearing men as to whether they have had any experience with curing oil-pumping in annular ball-bearings.

If there is an existing standard on the radius of the groove in the races, is it 7/10 of the ball diameter or do the different makes of bearing have different radius grooves? If they do, would it not be necessary to have a table for each make of bearing?

R. S. DRUMMOND[2]:—We have had some experience in our factory along the same line that Mr. Brodie mentions, concerning the radial clearance of ball bearings. The work that Mr. Brodie mentions in his paper is confirmed by experience in testing gears in our factory. The tests were suggested by gears that were quiet with plain bearings and noisy with other bearings, and were made using Hess-Bright bearings of various radial clearance. I speak of this with reference to automobile transmissions only, as there appear to be other fields of usefulness for ball and roller bearings which are not as yet affected by close fit of balls.

We have upward of 15 different transmissions, representing a number of cars that are produced by men present in this room. These were furnished us by the car builders for test purposes. In every case the bearings in the transmissions require some alteration in the amount of radial clearance for them to operate quietly. Comment has been made about the amount of radial clearance or oil room needed. There are no statistics that are absolute on that subject today. The amount mentioned in Mr. Brodie's paper, 0.0008 in., is approximately correct under average conditions in average transmissions as tested by us. Where there are no means of checking in a laboratory the amount of clearance in the bearing, we have used a very simple expedient. We hold rigidly with one hand the inner race, and the cage carrying the balls and try to slip the outer race over the balls. A crude but very satisfactory estimate of the amount of radial clearance can be made in this way. If the outer race slips in that way, there is normally enough radial clearance. In four noisy transmission jobs investigated in the factories of the manufacturers, we established to their satisfaction that the radial clearance was lacking to an extent that developed noise in the bearings and that noise was eliminated by increasing radial clearance. Our tests confirm what Mr. Brodie has said.

Our experience indicates the same general result from the standpoint of backlash in gears. In cold weather the teeth operate somewhat like individual dashpots. The oil does not always get away with facility at the bottom of the tooth; it has to be squeezed out under pressure and, if there is not sufficient room for the oil to escape readily, a noise will develop. Backlash in various types of gear and in various transmissions depends to a certain extent upon the construction. There is one transmission that requires approximately 0.004-in. backlash to operate with any reasonable degree of quietness. We believe this is due to poor support of the driving pinion. When this support is improved the gears run quietly with greater backlash. Average transmissions show a requirement somewhere between 0.010 and 0.016-in. backlash.

T. C. DELAVAL-CROW[2]:—Mention is made in the paper of the effect of radial clearance in ball and roller bearings on transmission noise. The author's experience indicated that an increase of radial clearance within certain limits reduced the noise. The reason advanced for this is that sufficient space was left for an oil-film between the balls and the races. The experience of the New Departure engineers corroborates the results obtained by Messrs. Crain and Brodie but we cannot agree with the reasons advanced for the reduction in noise, as the very heavy unit-pressures at the contact points of the balls with their races absolutely preclude the presence of an oil-film in the commonly accepted sense of the term and, therefore, it seems that some other reason should be assigned for the reduction of noise.

A study of the noise problems indicates that there are two main causes, namely, noise due to faulty tooth-contact arising either from an imperfect tooth-form or from a misalignment of the transmission parts in assembly, and the secondary cause that might be traced to the inherent structure of the bearings themselves and their mounting. The trained ear can easily distinguish between the two causes of noise, that caused by the bearing being a distinct whistle and that from the gears a growl. In many cases the modification of the bearing structure and mounting will alleviate the noise due to faulty tooth-contact of form. Our experience indicates that there is no general rule as to the degree of modification of the bearing structure that will lessen noise in all cases. Each particular transmission is a study in itself, the design of the transmission housing having a very great influence on the degree of amplification of noise vibrations.

As a general thing, attempts have been made to use ball bearings with no radial clearance, little regard being paid to the effect of the expansion of the inner race due

[2] M.S.A.E.—Vice-President, Gear Grinding Machine Co., Detroit.
[3] M.S.A.E.—Chief engineer, New Departure Mfg. Co., Bristol, Conn.

to excessively heavy press-fits on shafts and to too tight fits of outer races in housings. When assembled under these conditions, the bearings themselves will have a distinctive whistling noise due to the vibration set up through the metallic parts under tension, as in the case of a piano string. Noise such as this can be decreased or practically eliminated entirely through the lessening of the press fit on the shaft and the reduction or elimination of the tightness of the fit of the outer race in the bearing housing. It is essential that the outer race be not a tight fit in its housing, due to the fact that it is practically impossible, as a production proposition, to produce housings accurately round, and the extension of out-of-roundness of the housing is transmitted to the ball race of the bearing on account of the deformation of the outer race.

An example of the influence of the housing out-of-roundness on the race ring may be cited from an experiment conducted with a light aluminum housing of an average thickness of 0.1870 in. about the bearing seat which when accurately measured was found to be 0.0006 in. out-of-round in the bore. Into this was inserted with a very light press-fit, a plain bearing ring of high-carbon chrome steel, having a width of 0.6693 in., a section of 0.2960 sq. in. and a base diameter of 2.4410 in., which was lapped to a perfect ring on both the outer diameter and the bore, and accurately measured before insertion into the housing. Upon being inserted into the housing which, as has been previously said, was approximately 0.0006 in. out-of-round, the bore of the ring was found to be 0.0004 in. out-of-round. Upon the reduction of the fit in the housing from a press to a push fit, the out-of-roundness of the ring was eliminated. The expansion of inner-race rings of bearings due to press fits on shafts is likewise often neglected. Investigations have shown that the increase in the diameter of the inner raceway is dependent on two things: the amount of fit used and the relation of the race thickness to the shaft diameter.

A study of the chart at the left of Fig. 1 will show that a press fit greater than 0.0005 in. is detrimental, because the race expansion increases very rapidly above this point, and is also liable to make trouble in assembly due to scoring of the shaft, causing insecure seating and possible misalignment. It is also seen that for a given increase in the shaft diameter the expansion of the cone raceway is greater in the case of the No. 1310 bearing than in that of the No. 1307.

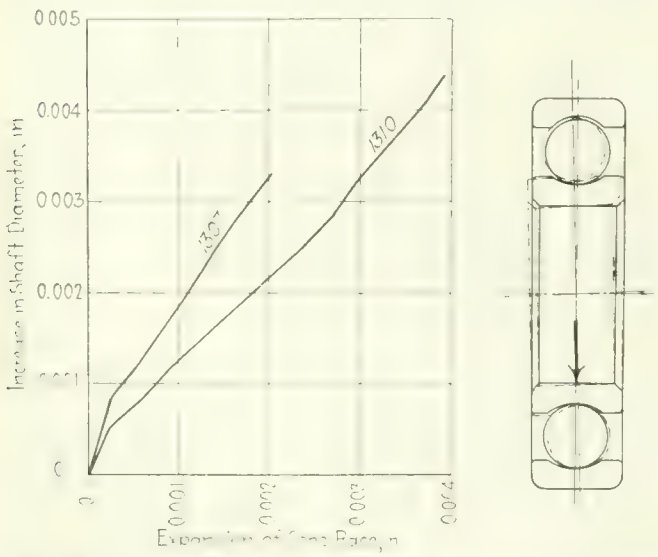

Fig. 1—The Chart at the Left Shows the Relation between the Shaft Diameter and the Expansion of a Cone Raceway in a Ball Bearing, While the Drawing at the Right Illustrates How Much It Is Possible for the Shaft on Which the Inner Raceway Is Mounted To Deflect before the Uppermost Balls Make Forced Contact with the Upper Portion of the Outer Race

Considering the fact that the bearing is used merely to support the rotating members and not as a means of transmitting torque, the use of an excessive press-fit is not necessary. The press fit need be only great enough to assure that the circumference of the shaft is larger than that of the cone bore, in which case no slippage can occur and consequently no wear or peening of the shaft take place.

It is the practice of the New Departure Mfg. Co. in the production of its ball bearings to allow sufficient radial clearance between the balls and their races to compensate for inner-race expansion due to average press-fits not in excess of 0.0005 in. and in addition to allow a very slight excess of clearance to take care of the possible misalignment of bearings in housings or of the transmission shafts in assembly.

A fact that is not as generally recognized as it should be is that in properly constructed ball-bearings provided with slight amounts of radial clearance there is very marked ability to operate satisfactorily under conditions of shaft and housing misalignment. This is due to the fact that in the presence of clearance with other than gravitational load, the inner race and the lower balls will establish perfect contact with the outer race at the lower side, leaving all of the clearance on the upper side between the uppermost balls and the outer race, so that, as illustrated at the right of Fig. 1, the shaft upon which the inner race is mounted can deflect about a suitable angle before the uppermost balls come into force contact with the upper portion of the outer race. Under actual running conditions the clearance between the uppermost balls is greater than under static conditions, due to the deformation of the races and the balls under load, so that the angularity of shaft deflection transmittable under these conditions is in direct proportion to the amount of load on the bearings.

It will be seen that, if the radius of curvature of the outer race approximates the radius of the ball too closely, the ability of the bearing to withstand ordinary deflection misalignments is greatly reduced, in spite of the fact that there may be built into the bearing a relatively large amount of radial clearance.

Our experience has indicated that it is possible to lessen seriously the availability of a given bearing, through the establishment of too close race curvatures, especially in the outer race, to carry ordinary deflections or misalignments without excessive noise. While, in a properly designed and manufactured ball-bearing, a limited amount of radial play is desirable for the reasons given above, it can be seen readily that excessive radial clearance may become detrimental to the load-carrying ability of the bearing in that when there is excessive radial clearance the diameter of the ball race in the outer race is materially greater than the sum of the diameters of the ball race of the inner race plus two ball diameters, causing the radial load of the bearing to be carried on two or three balls rather than on half of the balls in the bearing.

As stated by Messrs. Crain and Brodie, it is practically impossible to measure radial play. We therefore advocate that the measurement of end play under a known load be used as an indication of the radial clearance existing in the bearing. It is well to remember that this means of measuring is only an indication, as the mathe-

matical relation of the radial clearance to the end play is dependent on the percentage of the ball diameter to which the race radius is ground and a very slight change in this percentage makes a relatively large change in the end play obtained for a given amount of radial clearance. The race radius on all high quality ball-bearings is ground by a generating grinder and any change in the race diameter from the standard set-up causes an equal change in the race radius, therefore causing a variation in the end-play relation to the radial clearance.

SOME UNIQUE FEATURES OF AUTOMOBILE PRODUCTION

BY WILLIAM DUNK

THE author discusses the Franklin automobile designs in regard to the production of an air-cooled cylinder, the making of case-hardened crankshafts and the machining of duralumin connecting-rods, commenting also upon experiments made with a view to producing hot-swaged rear-axle drive-shafts.

The unit-cylinder construction of the Franklin engine, with the cylinder-head cast integrally with the body of the casting and steel cooling-fins cast in the outer surface of the cylinder-wall, presents a different problem from that of machining cylinders cast-in-block, and the procedure is described in some detail, inclusive of the machine tools used. The case-hardened crankshaft and the duralumin connecting-rod are treated in a similar manner. The experiments in the manufacture of a hot-swaged rear-axle drive-shaft have extended over the past 18 months, but have not yet justified quantity production by this method.—[Printed in the November, 1922, issue of THE JOURNAL.]

THE DISCUSSION

K. L. HERRMANN:—What percentage of cylinder scrap does the Franklin company have in connection with its production of cylinders?

W. H. WORTHINGTON:—In connection with bearings, what lubricating system is employed? Of what material are the bearings made? Is the bearing surface of bronze or of babbitt metal? What clearance for oil is provided in the selective reaming?

J. H. CLARK:—Are oil-grooves used in connecting-rods and camshaft bearings?

R. H. WEINERT:—Why is it necessary to produce a smooth finish on the axle-shafts? Is it because this finish is necessary for some of the operations? What effect does scaling have? On the axles that we produce we always have scaling marks, but we find that they do not affect our production in any way.

E. PLANCHÉ:—What percentage of rejection does the Franklin company have on duralumin connecting-rods? Does it have any breakage?

ROBERT K. JACK:—Is any trouble experienced in cold weather due to this type of engine cooling off very rapidly when it is stopped, on account of the absence of water around the bores, which, on a water-cooled engine, retains its heat for a considerable length of time. Is it necessary to carry a larger battery than would be required for a water-cooled engine of the same displacement, due to the extra drain on the battery from repeatedly cranking a cold engine?

T. J. LITLE, JR.:—What is the compression pressure of the Franklin engine? How much weight was saved by the use of the duralumin connecting-rod instead of the former steel rod?

PRESIDENT BACHMAN:—I am interested in the portions of the paper relating to the case-hardened crankshaft, scleroscope values of 80 to 100 being mentioned. Has any of the experimental work indicated a remarkable difference between these values and values in the neighborhood of 70? What has been the experience with regard to copper-plating surfaces of the crankshaft? Are any preliminary finishing operations necessary to get a reasonably smooth surface on the crankshaft for that purpose, or does the ordinary finish cover the matter satisfactorily?

B. M. LEECE:—I request information particularly in regard to the hardening die used on the crankshaft.

MR. HERRMANN:—In the Studebaker plants we roll axle-shafts instead of swaging them. We use no die in rolling them, we require but one heat and the machinery stands up and gives us no trouble at all. The swaging of the crankshaft may be a different proposition entirely.

H. P. HARRISON[1]:—In answer to Mr. Herrmann's remarks, I would say that our engineers have designed a rear-axle drive-shaft that is extremely light. For this reason they insist on a perfect circular section of the shaft and a perfect taper from the large to the small end. We have not been able to convince them that we could produce a rolled shaft which would be good enough to meet their requirements.

Foundry scrap, in connection with the cylinder, averages about 10 per cent. We realize that this is rather a small figure, but it is made so by the fact that the cooling fins are inserted in the cylinder wall only 1/16 in. Should we insert them any deeper than that, we would surely have trouble with cylinders splitting in service on account of the extremely thin wall left between the bottom of the flange and the bore of the cylinder. The amount of our machine-shop scrap runs very low; 1 per cent will cover it at all times. I believe that this is due primarily to an excessively good inspection of the cylinder castings and the comparatively simple machining operation that the unit cylinder requires.

We use a pressure system of lubrication with a central oil-pump, carrying a pressure of about 80 lb. per sq. in for the main and crankpin bearings. The bearing metal is a hard type of die-cast babbitt. We do not use what are considered true oil-grooves in the Franklin bearing, but simply a small pocket that is cast entirely through the back of the bearing, making an opening about 5/16 in. wide and ½ in. long. This connects directly with an oil lead from the pump.

The oil clearance that we use with the selective method of reaming is 0.001 in. We find that this gives a very quiet engine and at the same time a new engine is free enough to start easily.

My answer to Mr. Herrmann explains somewhat the reason our engineers insist on a smooth finish on the rear-axle drive-shaft. We are working so close to the ultimate strength of this shaft that we cannot have the least suspicion of an abrasion in the surface of the shaft at the neck. The scaling that I mentioned seems to have the

[1] Production department, H. H. Franklin Mfg. Co., Syracuse, N. Y.

effect of making rather deep abrasions during the swaging process.

We have never had a duralumin connecting-rod fail in service. This is rather a remarkable record for putting a new part like that into an engine but, as yet, we have experienced no trouble whatever from this source.

In regard to starting the Franklin engine in cold weather, due to the excessive cooling effect of the fan as soon as the engine is started up with the starting motor, we use an electric primer in connection with the carbureter; it is used to warm the gasoline itself before it passes into the venturi tube and so on into the manifold. This has the result of vaporizing the starting charge quickly. We experience no trouble whatever in starting in cold weather.

The pressure cooling-system we are using now allows us to carry a compression pressure of about 4 atmospheres, which gives us considerable increase in power over that of the engine we have just abandoned.

The relative weights of the steel connecting-rod formerly used and the duralumin connecting-rod we are using now are as follows: the steel rod weighed slightly more than 2 lb.; the duralumin rod weighs but 13 oz. This decreased weight has the direct effect of reducing the amount of engine vibration. The steel rod was designed for a crankpin bearing of only 1⅝-in. diameter, while the duralumin rod was made to take a 2-in. crankpin bearing.

We have had some shafts go through which scleroscoped as low as 75 at some points, and they gave us no trouble at all. The principal reason for keeping the requirements as high as they are is to endeavor to reach the maximum rather than to lower the requirements, which might induce the heat-treating department to make an insufficient effort to get a shaft that can really be called hard.

In preparing the crankshaft for copper-plating, we do not find it necessary to machine the surfaces that are to be plated. The forging is simply blasted with metal-abrasive shot, and the copper-plating is applied directly to the surface. We have had no trouble due to failure of the copper to adhere properly to the forged surfaces. It is necessary to have the copper adhere only long enough to take the shaft through the carburizing process.

The hardening *die* we use is an evolution of many ideas that we tried out. It operates exactly like a pair of hinged doors that have V-blocks on their inner surfaces. The V-blocks are made of high-speed steel and have contact points on the bearing surfaces only 3/16 in. wide. There are eight of these contact points on each bearing, and they cover a very small area when compared with the total bearing area of the bearing in question.

SOME CAUSES OF GEAR-TOOTH ERRORS AND THEIR DETECTION

BY K. L. HERRMANN

THE different gear noises are classified under the names of knock, rattle, growl, hum and sing, and these are discussed at some length, examples of defects that cause noise being given and a device for checking tooth spacing being illustrated and described. An instrument for analyzing tooth-forms that produce these different noises is explained and illustrated.

Causes of the errors in gears may be in the hardening process, in the cutting machines or in the cutters. A hobbing machine is used as an example and its possibilities for error are commented upon. Tooth-forms are illustrated and treated briefly, and the hardening of gears and the grinding of gear-tooth forms are given similar attention.—[Printed in the November, 1922, issue of THE JOURNAL.]

THE DISCUSSION

J. F. RAND:—Were the gears that we have been discussing finished in one cut? If not, how much material was left on them for the finisher? What type of machine finished them, a hobbing or a gear-shaping machine? We find it advisable to attempt to build a special machine of our own to overcome the indexing trouble mentioned.

O. LINDBERG:—We have found it impossible to produce an accurate gear with a gear-hobbing machine. We have used gear-hobbing machines only for roughing purposes, and use a gear-shaping machine for finishing.

C. F. SCOTT:—Many of the British and French cars are built with relatively small engines for economical reasons. The cars are fitted with four-speed gearboxes and much gearshifting is necessary, which might not be acceptable in this Country. These gearsets are, some of them, direct-drive on third, and some drive direct on fourth speed but, in any event, at one of the two top speeds they would be comparatively noisy. Would the noise at either top speed be considered excessive in accordance with American standards, or is the transmission fairly quiet? If so, how do they make it quiet?

MR. RAND:—What is Mr. Herrmann's opinion regarding just how far one can go with spiral angles? In other words, suppose a 30-deg. spiral angle on a given diameter of gear of a certain pitch, is it an advantage to go over 30 or 35 deg.? What is the limiting factor on that spiral angle?

A. J. BAKER[*]:—The essential point Mr. Herrmann brought out is how difficult it is to maintain the proper operation of the gear-cutting machine. When it is considered that this machine, no matter of what type, is composed of two rotating members, each subject to eccentricities due to the initial errors brought about during their manufacture, and that those errors can be added to by temperature conditions, stresses, material variations and relative dullness of the cutting portions, we are forced to the conclusion that the whole principle is wrong.

It is of little use to make a statement of that kind unless some constructive criticism is offered. Do the gear-cutting-machine builders give any consideration to the use of a single-point finishing-tool, such as a broach, in conjunction with the rotating work, so as to eliminate all of those points that give trouble? I have in mind that a single-point tooth for the actual finishing tool can be made far more accurately than it is possible to produce a number of cutting tools, each of which has a different relation to the true axis of rotation. That is applicable, I believe, to only a straight spur-gear, but we would all be happy if we could eliminate some of our spur-gear troubles.

MR. DRUMMOND:—The indicating apparatus shown by Mr. Herrmann is well known to me. I admire the work

[*] Research Engineer, Willys Overland Co., Toledo.

that he has done. He is more or less a pioneer in the study of tooth-form. The efforts to develop mechanisms for measuring gear teeth are very worthy. Many types of measuring apparatus are being offered today. In the interest of good gearing, they should be given careful attention because they are worthwhile.

I am also interested in grinding operations and in tooth-form error or distortion. The transmission Mr. Herrmann is working on is one of the most difficult transmissions in America to make quiet. It is a combination of 16 and 32-tooth gears and a rear gear having 13 teeth that drives a 14-tooth gear. The teeth are stub teeth and the pressure-angle is 14½ deg. If you will figure it out and then cut some of these gears in your own factories, I think you will look at the charts again with more interest and pay greater attention to the subject of measuring gear-tooth form. The transmission in question is hard to build, but this is being done successfully.

Mention was made of a machine that would have a broaching action. Gear teeth can be and have been broached. We are using the shaping-type machine with a grinding-wheel form to fit the two sides, which is more-or-less similar to the broach in its action. Regardless of our own individual method of doing this work, we think that the future of the industry lies in the direction of doing final work after the distortion takes place. We are not opposed in any way to doing it by any other method, but I think there will be difficulty in making hardened gears until we do final work after distortion.

The variation in gears that Mr. Herrmann speaks of sometimes takes peculiar form. We have on record a gear that had a number of teeth, going half-way around the gear, with an index error as high as 0.015-in., but gear noise in the transmission was remarkably slight.

MR. HERRMANN:—It is true that grinding can be resorted to. We have had rather wonderful success with such a machine for the past 2 months. In this particular grinding process, however, it is necessary that the gear be fairly accurate; otherwise the output of the machine is very limited. We are getting gears with less than 0.4-per cent rejection when ground on this machine. However, grinding alone does not solve the problem. We do not need to harden some gears. Some gears are spiral. They involve a somewhat more expensive process than we can afford to use in connection with a medium-price car. Spiral-bevel-gear grinding is unknown to us at this time.

The gears mentioned in the paper were roughed-out first and then finished in a more accurate machine that is more carefully maintained. It is possible to hob an accurate gear. Gears can be hobbed as accurately as they can be cut on a shaping machine.

The practice in Europe is entirely different from that in America. Some years ago I worked as a toolmaker at the Napier plant in London. When producing only a few cars per week, many things can be done that cannot be done in large production. European gears are much quieter. The work put upon them makes them so.

I do not know whether a 30-deg. spiral angle is better than 45 deg., which we use to a large extent. The spiral angle, as well as the pressure-angle, and tooth heights of full or short length, seem to have very little to do with the matter if the other errors are within proper limits. I prefer the steeper angle.

As to the necessity of a new gear-cutting machine, most of the important gear-cutting-machine builders are designing new machinery.

Silent chains help to reduce noise in a motor car. They offer many problems. I refer you to the service divisions of the companies that use them. Accuracy of gear-tooth form is necessary; otherwise silent chains are noisy. The same principles that have been discussed here in connection with gears can be discussed in connection with silent chains.

After we do the best we can with gears and get them just as nearly right as we can measure, the gear situation costs the motor-car manufacturers $11,000 per day. We estimate that this figure represents the lowest possible amount that is being spent on this problem.

A. B. REYNDERS:—One of the principal reasons for using plain bearings on lighting generators is the quieter operation in comparison with ball bearings running at high speeds.

Owing to the fact that no absolute standard of noise is available, there are about as many different opinions with regard to quiet operation as there are persons judging the apparatus. To eliminate this difference of opinion we should have some sort of a noise-measuring device or some kind of a standard. At present we select a machine which, in the opinion of a number of people, is considered quiet. This machine is set aside as a standard and production is obtained by making comparisons with this standard. Is a more accurate method available at the present time in the manufacture of automotive parts?

MR. PLANCHÉ:—It is a recognized fact that gear noise is very intimately connected with the pitch sizes of gears. A noise is created by a metallic vibration. This metallic vibration is produced by the impact of one gear tooth against another. The greater the pitch for a given diameter, the greater is the interval between each impact for the same speed. I am sure that, if the engineers would turn their thoughts to the utilization of a smaller tooth-pitch, widening the gear if necessary to preserve the strength, many of our gear problems would be eliminated or greatly decreased. To confirm this opinion, we have only to study the steam turbine in which the use of small-pitch spiral-type gears of great width has been very successful in transmitting power with the minimum amount of noise.

THE GROUP-BONUS WAGE-INCENTIVE PLAN

BY E. KARL WENNERLUND

THE author states that the purposes of every plan of wage incentive are to stimulate the worker to a greater effort than is generally obtained on a straight day-work basis; to reward him somewhat in proportion to his effort; and the gaining of other advantages such as greater attention to conditions that curtail production, more uniform labor costs and the elimination of inefficient employes. He states further that nearly all industries engaged in repetitive work are now on an incentive basis.

After outlining the most successful wage-incentive plans and enumerating some of the conditions that must be met, inclusive of four specific fundamental principles of industry that are stated, the group-bonus plan is explained and the application of group standard-time is discussed at some length, supplemented by tabular data. Experience with grouping is then related and conditions favorable to grouping are mentioned. The summary states that the group plan, like any other wage-incentive plan, has for its main objec-

tive intensive production.—[Printed in the November, 1922, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN H. W. ALDEN:—What effect has this group-bonus wage-incentive plan had on the inspection problem in the plant? Has it decreased the ratio of inspectors to producers and improved the general quality and output of the product?

A. J. SCAIFE:—How is the individual rewarded in each group? How does the reward of the man old in the service compare with that of the man just employed, and how do the rewards of the efficient and the inefficient workers differ?

JAMES H. MARKS:—What procedure is followed with respect to his bonus in the case of a man who is discharged or quits during the pay period?

We also have installed a group-bonus system in our plant that is very similar to that of Mr. Wennerlund, although I believe that our groups as a whole are somewhat larger than his, as we have grouped entire departments. The basis of bonus that we use is certain standards of efficiency that we have determined for machine operators, assembly men, molders, steam-hammer men and others. We have set various standards of efficiency rather than use one of 80 per cent as described by Mr. Wennerlund. We offer a 1-per cent bonus for each point that the group efficiency exceeds the predetermined standard of efficiency. We take care to have varying rates per hour for the different employes in the group, in proportion to their speed and ability. What is meant when the efficiency of the group exceeds 100 per cent?

S. W. TAYLOR:—I worked for Mr. Wennerlund for a number of years. We based our time-studies on 100-per cent production for the good average worker.

J. C. WILLIAM SMITH:—At the Willys-Overland plant in Toledo we use a similar plan, but it is straight piece-work and each man in the group is assigned a specific piece-price that is paid him for each operation he performs. For example, in our gear-housing group there are eight Gisholt machines, together with numerous other machines; if the group turns out 500 housings at the end of the line, for the day, we pay each man in the group for 500 housings. Where there is more than one machine on the same operation, as in the case of the eight Gisholts, the pay is divided equally between the eight men, if agreeable to them. If not, each man is paid for the number of housings on which he performed the operation, but the total paid for does not exceed 500. The foreman makes the decision as to the number, if the men do not agree. In this way we have done away entirely with the job tickets mentioned by Mr. Wennerlund. The method obviates paying for the gear housings before they are actually received. It gives us the individual efficiency of each operator and reduces the number of our inspectors, checkers and truckers, as the work does not touch the floor. It demonstrates to each man that he is paid exactly for the work performed. We use guaranteed piece-work prices and the price is not changed before the end of a year.

W. G. CAREINS:—I am connected with the Milwaukee plant of the Nash Motors Co. We use group-bonus plans. We use some straight piece-work and, in fact, we are not partial to any one system, but use what we think is best adapted to the particular line of work in hand. In case a new man comes into a group to perform an operation that requires some time for him to become proficient in it and to develop a standard rate of production, such as the instance cited of the Gisholt machines, we would pay him the day rate for a certain length of time, perhaps 1 week, 10 days or 3 days, depending upon the length of time needed for him to become proficient. The other men in the group take the balance of the pay and split it among themselves.

In some departments where we use the group-bonus plan to provide an incentive to different classes of labor, we have what we call Class A, Class B and Class C men who take different proportions of the total bonus-price. We find that this works very satisfactorily; for instance, in engine tests, where a certain number of men probably handle the hoists, another class of men who are real engine mechanics do the class of work they are fitted for and a third group run the engines. In our Kenosha, Wis., plant, every operation is individual piece-work. This plant has never gone into the bonus plan or the group plan in any way.

H. K. REINOEHL:—Must the group be kept small so that the individual members can watch each other for the purpose of eliminating the poor producer?

E. BOUTON:—In a group-bonus plan, how are costs maintained level? There is a fluctuation of cost. When does Mr. Wennerlund arrive at a true cost, or an actual cost?

J. L. LANNEN:—What disposal is made of scrap?

J. A. MURRAY:—We have in the General Motors Truck Co. plant the group-bonus system, which was installed under Mr. Wennerlund's supervision. We have been operating this system for about 2½ years and I cannot say enough in its praise. It relieves me of a great amount of detail that we had to work out when operating under the individual-effort system and has reduced considerably the amount of clerical work in both our time-keeping and production departments.

We have approximately 525 machines at work on the group-bonus plan and they are split into 23 groups. Each group is really a plant in itself, inasmuch as there is a machine in each group or division for each operation and the work flows down the line progressively, passing only from machine to machine and never jumping across from one line to another.

We also maintain what we call a day-work well. This is built up when we install a line of machines or route new parts over the line. It naturally follows that during the trying-out of the group and the demonstration of tools, a number of parts are made which we pay for on the day-work basis. This number of hours is always held back from the operators and constitutes what we call a day-work well. We consider this well the same as a machine, the company owning it, inasmuch as we already have paid for the work done on the day-work basis. Our aim is to pay a bonus only for the parts actually produced on bonus. This well, as you will see, needs to be built up only once, and we maintain it until a group is either done away with or a new well is established.

E. KARL WENNERLUND:—The effect of the group-bonus plan upon inspection methods is that inspection must become more exacting as soon as an incentive plan is inaugurated; however, that is true of every plan. For example, the highest type of car might be built on straight day-work and some inspection would be necessary; but if that same car were built under a wage-incentive plan it would be done to speed-up production. Just as soon as production is speeded-up, the tendency, at least, is for the quality of the product to deteriorate. I do not wish, however, to convey the impression that the group-bonus system alone would cause this tendency but, with the factory organization remaining the same, additional inspectors are needed to counteract it.

In regard to inspection under the group-bonus system as compared with the inspection of individual piece-work, we have gradually developed certain practices. Under either plan there is the same inherent tendency to speed-up production and for quality to go down; so every piece or a certain percentage of pieces must be inspected in any event. Inspection is not eliminated or quality improved simply by introducing groups, but we are coming to the point where we pay for the good product only, unless it can be shown that the material from the manufacturer was defective or had defects when it came to the department. The result is that the group tries to turn out better work instead of trying only to get the work through.

For example, in a plant where we are introducing the group-bonus plan now, armatures for starting systems are tested and a certain percentage of them fails to pass inspection. It is very difficult to say that this is the fault of any one employe. Formerly, the armatures were laid aside and, when a certain number of them had accumulated, they would be sent through on a day-work ticket to be fixed. It was not practicable to deduct the cost from anybody's pay, because it was impossible to determine who caused the trouble. We told these employes that we would pay only for the good armatures and that we had found the defective ones to constitute about 2 per cent of the total number. Therefore, we said we would add 2 per cent to the time standard, so that, if the defects ran higher than that, there would be a fine against the men. On the other hand, if this proved to be unfair, we would adjust it. Now, when a defective armature comes through, the tendency is for the inspector to throw it back into the line, and we do not have to get the elapsed time for fixing it. We used to get time tickets that were charged to expense.

Defective products fall into one of two classes; the first is defective work that can be corrected, and the other is simply junk. If the product has to be scrapped, this is done just the same as under the individual-effort system. If it can be fixed on the line, it is sent back without any ticket and without any credits. That plan has had a very good effect in standardizing our defective work.

As to the division of earnings, there may be a man in the group on an operation that requires great skill, the result of years of service, and he may have to work to limits that are within 0.0005 in. In the same group there may be a boy who drills little pin-holes on a vertical drilling machine. He places the piece in a jig and could not spoil it if he tried. Naturally, the skilful man should not have the same earnings as the boy. In this particular case we paid the skilled man a base rate of 60 cents per hr. and the boy 30 cents per hr. The efficiency of that group at the end of the pay period might be 110-per cent production. If so, each member of the group would get a 32-per cent bonus on his earnings. If each worked 100 hr., the mechanic would get $60 flat rate with 32 per cent added and the boy would get $30 flat rate and 32 per cent additional. That plan takes care of all of our division of earnings. Sometimes we have girls working on a small bench-operation and we may have a skilled mechanic on the very next operation; it would not be fair to them or to any one to divide their earnings equally.

The case of the worker who is discharged, or who quits, was a little troublesome at first. We used to tell them we would give them straight pay and that at the end of the pay period we would give them the bonus they had earned. Sometimes such men left and did not know where they were going, so that plan did not work out very satisfactorily. Furthermore, our State law is rather strict; it requires that, if a man is discharged, he must be paid that same day. We adopted a very good working rule by taking the average efficiency of the group up to the end of the previous day, and figuring the bonus on that basis for the workman who leaves the service. For example, suppose the pay period to have extended 5 days and that the workman quits today at noon. He might be discharged; if so, we are compelled to pay him his actual flat-rate multiplied by the hours he has worked, the same as for straight day-work. But we are under a moral obligation, at least, to pay him a bonus; so we take the efficiency up to the previous night. It may be 90 or 100 per cent, and it may not be the same as at the end of the pay period but, so far as the company is concerned, it follows the law of averages, being sometimes a little over and sometimes a little under. It seems to be entirely satisfactory to our men, and we have had no complaints. A man seems to think it is entirely fair if he gets his straight pay plus the bonus up to the last night on the basis of average efficiency; so it has worked out very simply.

Concerning the size of a group, we must all concede that the individual-effort incentive is right, and we find that we must secure the individual interest of the employe in his own effort. He must be placed right next to his team-mates and on similar work. In isolated cases one can do almost anything, but certain fundamental principles apply to groups and one cannot get very far away from them.

We started a complicated job recently at one of our large factories that employs about 2000 people. The first operation was performed by about eight girls each of whom did exactly the same thing, picking up little bars and measuring them with micrometer calipers. The next major operation was assembling, done by probably 8 to 10 persons, who put a bushing in and fastened it. The next group, 8 to 10 men, did the machine work. It would be a mistake to put all of these operatives in one gang or one group. The girls on the first operation knew nothing about the machine work. Assuming that the group became reduced from eight to seven because of one who quit, seven operatives would get the pay of eight. If this amount were spread out among a lot of other operatives, the group would not get the benefit of it; so, we try to keep our groups fairly small, to localize the interest. When we wanted to group the girls who performed the first operation, they objected on the ground that two of them were slow operators; so, the slow ones were replaced by faster workers.

The primary object of the group-bonus plan was to reduce the amount of clerical work. We found later that this is only a minor consideration. The big effect is in increasing production because the slow workers are eliminated, and those who remain help each other out on certain operations, all along the line.

As to what is meant when the group efficiency exceeds 100 per cent, the question should be: "What do you mean by 100 per cent?" It means whatever meaning is given it. The standard time for an operation is the time taken repeatedly by the average competent workman, over an extended period and eliminating lost and waste time. It is not the time in which the operation can be done by an expert. The efficiency measurement is the standard time divided by the actual time, and 100 per cent on production is the average time made by the average competent workman. For example, a good workman ought to dig a certain number of feet of ditch in a day; another man

may dig only half as much and a third man may dig 25 per cent more; the efficiency measurement is from an assumed standard that we called "standard time."

In regard to new men who enter the group, we found it a good plan to carry a new man for 3 days and at the end of that period to throw him automatically into the group unless the superintendent asks specifically to have the probation time extended. The effect is that the company carries the new man for 3 days and the men in the group carry him for the following 3 days; after that it is up to the man to make-good in the group.

Another method which, in principle, amounts to the same thing, is to charge half of the new man's time to the group and the other half to the expense account and not to allow the man to participate in the bonus while he is on that basis. The effect is that the group carries only half of the new man's time, and he does not get the bonus and therefore tries to enter the group. That works out very well.

The question regarding the proper size of a group and why it should be small has to do with individual effort. The worker should be able to see that the output depends upon his own efforts. As an illustration, we had 20 men snagging castings. Handling this work on an individual basis was very difficult because we had to weigh all the castings for each man and keep track of them. To handle them on a day-work basis would have required about 30 instead of 20 men; so, we placed them all in one group and took the foundry report for a certain number of pounds per day, and allowed a certain number of man-hours per 1000 lb. That plan worked well. We dispensed with from six to eight men that had been required under the individual-effort system. The only reason we could get the men to work under this plan was that they had an incentive to increase the output. If we had tried to group them with the molders, for instance, we would not have got anywhere. The plan demands very close co-operation; the men must be near together so they can see that every man's efforts count. A certain output from a group costs us a certain amount of money and, if we are making only one part, the cost of the group operation is the money we pay divided by the number of pieces we obtain. That is positive and actual. We may have various operations going through the group. We may have a heat-treating group in which there are as many as 80 different parts, ranging all the way from small washers to front axles. There may be 20 to 30 men, split into various groups that perform the different operations. We can determine the cost because every one of those pieces has its own standard time. The time in which a front axle goes through is known to be a certain number of minutes or tenths of hour and, if a washer has to be hardened, that would represent a smaller unit of time. When the pay period closes we know certain positive facts. We know the amount of money paid out and the number of pieces produced and we have a standard time-value on each one. We determine the total number of actual man-hours in a group and the total number of standard man-hours and can therefore compute the cost per standard hour. For example, if each standard hour costs us 54 cents and the standard time on a certain product was 0.1 hr., the cost would be $0.054. Above 100 per cent, the cost is uniform. If the efficiency runs down to 90 per cent, the bonus decreases 10 per cent and our costs increase about 1.5 per cent. If the efficiency is reduced to 50 per cent, the cost increases; but, whatever the cost is, it can be computed.

We have very uniform costs. Under the group-bonus plan the cost efficiency is maintained above 90 and 100 per cent fairly well, and we get a uniform cost for given base-rates. No matter how many or how few pieces go through, or how many dividends there are, we can always determine the costs.

The general superintendent of an important factory that has been using the group-bonus system for about 5 months wrote me as follows:

> The results shown already are certainly most gratifying to us and substantiate our belief that the complete installation of this system in our factory will result in a wonderful saving to our company. A rough average of the results disclosed about a 23-per cent reduction in the number of employes, compared with the old method, 20-per cent increased real earnings for employees, and 49-per cent increased man-hour production.
>
> As you are aware, we installed this system a small group at a time, explaining to the employes its advantages to them and to the company, and in no instance have we had any difficulty in throwing-in additional groups. We are frank to say that the company and the employes are sold 100 per cent on this system, and the factory in general is benefited under this new method of working, as it is more quiet and orderly than under the old method. We hope to complete the necessary details and to have all operations working under this system by the first of the year.

To show why these men are taking-up this group-bonus system, I will include an extract from a letter written by the general manager of a company that builds a well-known car. He says:

> After years of experience, I am of the opinion that the group-bonus system is the best system adaptable not only to progressive manufacturing, but to other classes of work where the measurement of individual production would be expensive or burdensome. We are using the group-bonus plan because we feel that it is better adapted to our needs than the former individual-effort system, and that it is much more satisfactory than the usual piece-work system to both the management and our employes. Our experience during the past year has confirmed our views on this subject.

Another extract from an unsolicited letter by the general superintendent and the chief executive officer in one of the largest automobile factories in this Country is as follows:

> In regard to the group-bonus wage-incentive system, one of the first benefits is a doing away with a large number of clerks and carriers that were necessary under the old method of payment. We have found also that we have less labor trouble. I believe this is because the men take more interest in their work. We have found also that we are getting more production where we have this system thoroughly worked out. Another item of interest is the fact that we have reduced the percentage of scrap.

This last factory was formerly 100 per cent on the individual-effort system and had been ever since its start. It had worked on the individual-effort system for years. It was turned over to a group-bonus plan a few years ago and is still operating that way.

I wish to show that the factory managers who have taken this up and have tried it are with us on the proposition. I have received other letters along the same line. Unless these men were with us and found the group-bonus plan to be the right thing, there would be no use trying to put it through. It succeeds because each one who tackles it right and gives it proper cooperation, becomes one of our good friends and boosters.

Aircraft-Engine Practice as Applied to Air-Cooled Passenger-Car Engines

By S. D. Heron[1]

Annual Meeting Paper *Illustrated with* Drawings and Photographs

STATING that most of the copying of aircraft practice in post-war car-design has proved a failure because the fundamental difference in duty has not been realized, the author proposes to show wherein the automobile designer and the engine builder can profit by the use of practice developed for air-cooled aircraft engines and, after generalizing on the main considerations involved, discourses on the simplicity of layout of the efficient air-cooled cylinder as a preface to a somewhat detailed discussion regarding cylinder design and performance, inclusive of valve location, type of finning and form of cylinder-head.

Cylinder material, cooling surface, port arrangement for in-line engines, and the camshaft and valve-gear arrangement most desirable are subjects treated at length and illustrated, the thought then passing to a consideration of sleeve-valve types, temperature and exhaust-valve cooling, in such detail as to include many enlightening data; and similar treatment is accorded the subjects of air supply, a cooling system for in-line engines, air-blast direction and the necessary quantity of air. Desirable types of fan, spark-plug, piston and fuel are commented upon somewhat briefly. The author concludes (*a*) that scaling-down of design in internal-combustion-engine cylinders is a safe process, while scaling-up is decidedly unsound; (*b*) that, since thermal troubles have been the greatest cause of difficulty with air-cooled cars, a consideration of the designs capable of continuous full-throttle operation is likely to demonstrate the ease with which the relatively mild thermal difficulties of an air-cooled car can be overcome.

Appendix 1, by C. Fayette Taylor, treats the subject of the experimental development of air-cooled engine-cylinders specifically; it reviews briefly the methods used by the Engineering Division in developing and testing cylinder units for both air and water-cooled engines, and discusses some of the results obtained with several of the air-cooled cylinders mentioned in the paper proper. Performance investigations of experimental cylinders are described and commented upon, inclusive of illustrations and tabular data that are given rather lengthy attention. Laboratory experience in regard to exhaust-valve cooling is related, together with mention of the experimental results with internally cooled valves. Subsequently, many air and water-cooled-type comparisons are made, the conclusion being that there will be a rapid and healthy growth of the air-cooled type of powerplant for automotive vehicles.

Appendix 2, by E. H. Dix, Jr., has as its subject the foundry production of air-cooled cylinders with the fins cast integrally and first describes the experience of the Engineering Division foundry in casting aluminum-alloy cylinder-heads, numerous illustrations of castings being included. The suitable gating for aluminum-alloy casting is discussed, supplementary illustrations being presented, and the conclusion is reached that the experience related tends to show that air-cooled cylinder-head castings of the types illustrated are far from being bad production propositions.

THE aim of this paper is to show wherein the automobile designer and builder can profit by the use of practice developed for air-cooled aircraft engines. The aircraft-engine designer is apt to overemphasize the importance of full-throttle performance in car engines, forgetting that the modern automobile engine is essentially a smoothly rotating mechanism rather than a problem of intense heat-flow. Much of the slavish copying of aircraft practice in post-war car-design has proved a failure, because the fundamental difference in duty has not been realized. Nevertheless, it is felt that much of aircraft practice can be used in car design with good effect. There is no reason why more efficient and more uniform cylinder cooling and increased exhaust-valve durability should in any way reduce silence or smoothness. Rather the reverse is true, as an over-heated engine with distorted cylinders and leaky valves is not usually remarkable for either smoothness or mechanical silence.

The average automobile engineer derides aircraft-engine practice on the ground of assumptions such as that the exhaust-valves have to be discarded after 100 hr. of running, or that the whole engine has only a gross life of about 300 hr. of running. Neither of these assumptions happens to apply to modern engines or even to several 1914 and 1915 designs. It would be of interest to know how many modern car-engines are capable of running 100 hr. at three-quarter throttle for say 4000 miles, and what would be the relative condition of any passenger-car engine after such a test in comparison with an aircraft engine after a similar test. There is little question that the comparison would be altogether favorable to the aircraft engine. The rather grotesque attempts at exhaust-valve cooling evident in most cars, both air and water-cooled, lead to the conclusion that the use of aircraft practice would be productive of great improvement. Aircraft practice in this connection would result in greatly increased durability for equal cost.

The application of a large part of aircraft practice would not involve greater cost than that of present-day car-practice. Complication and expense do not necessarily spell efficiency, and crudity is not necessarily economy. Much of the crudity seen in air-cooled engines is decidedly very expensive.

Air-Cooled Cylinder Layout

Aircraft practice has shown how remarkably similar in layout the best air and water-cooled cylinders are. For both types, the layout with inclined overhead valves can be said to have proved most efficient as regards output, fuel economy and cooling. The successful air-cooled cylinder consists essentially of the body of a first-class water-cooled cylinder with the water-jacket replaced by

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suitable fins. The use of air-cooling does not involve throwing into the discard all of the experience gained in the construction of water-cooled engines, but rather the use of that knowledge with due consideration of the differing physical characteristics of the cooling medium.

The modern air-cooled aircraft-engine cylinder is admittedly expensive and apparently complicated in comparison with automobile-engine practice. It is, however, the necessity for minimum weight and sustained high specific output together with high thermal efficiency that is responsible for both the expensive built-up construction and the use of high-class material. High-duty air-cooled cylinders can be built of commercial materials throughout. Alloy-steel exhaust-valves are needed, but not more so than in present water-cooled types. A plain cast-iron cylinder-body with an aluminum piston and a chromium-steel exhaust-valve can, with suitable design, be made to cool efficiently and pull brake mean-effective pressures of over 100 lb. per sq. in. for prolonged periods with a full-throttle fuel-consumption of less than 0.6 lb. per b.hp-hr.

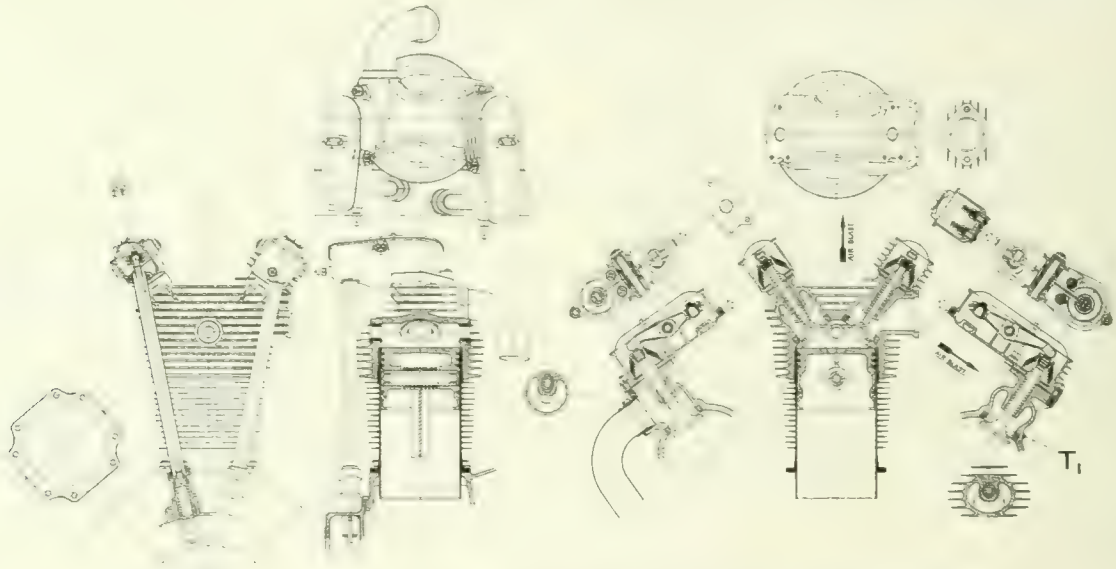


Fig. 1 Assembly Drawing of the Type-K Air-Cooled Cylinder

A modern air-cooled aircraft-cylinder is illustrated in Fig. 1. This has a cast aluminum head, screwed and shrunk onto an integrally finned steel-barrel. The valve-seat inserts are of aluminum bronze and are shrunk into the aluminum head, the head metal being peened over a shoulder on the inserts before the head and the seats are finish-machined. While the construction is undoubtedly expensive when measured by automobile standards, the production is really a straightforward proposition. The head casting is a very simple job, being produced with a stripper-plate pattern. It does not involve the use of any cores of loose pieces in the mold, has only a single-body core and, in addition, is cast without the use of chills. While the operations are lengthy, none of them is uncontrollable or uncertain.

This design bears comparison with proposed and existing automobile-engine designs having fins that are cast-in or otherwise attached in such a manner as largely to prohibit inspection of the soundness of attachment.

Cylinder Performance and Design

Owing to the high friction-loss in the universal-test engines used by the Engineering Division for single-cylinder testing, considerable disparity is evident in the apparent brake performance of different cylinders when they are of widely differing capacity. The author, therefore, in his portion of the paper, will correct the apparent brake performance to a constant-friction mean effective pressure of 15 lb. per sq. in., which is a fair average figure for a modern aircraft engine or a single-cylinder installation designed for minimum friction; brake horsepower, brake mean effective pressure and fuel consumption will be quoted on this basis.

A constant-friction mean effective pressure is really a much sounder basis to use than one of constant mechanical efficiency, since engines of similar construction except as regards cylinders usually have approximately an equal-friction mean effective pressure, although the brake mean effective pressure may vary widely and thus result in a considerable difference in the mechanical efficiency. In few cases is it possible to duplicate a single-cylinder output and fuel-consumption on multi-cylinder engines, and it may seem useless to quote such figures as they are at present generally impossible to attain. Nevertheless, such figures show the potential possibilities of the cylinders on multi-cylinder engines with suitable distribution systems, and indicate what can be and is done in certain cases, such as with radial aircraft engines with rotary mechanical distribution, if the charge be taken into the cylinder under similar conditions to those obtaining in a single-cylinder unit.

Very little reason has arisen for modification of the author's views on the subject of cylinder design during the last year. It will be necessary, however, for the sake of continuity to reiterate some of the ground covered in his last contribution to the Society on Some Aspects of Air-Cooled Cylinder Designs and Development.[2] Recent work has also given ground for a modification of some of the views previously held.

Valve Location and Type of Finning

The overhead valve-cylinder is superior to the side-valve type as regards output, cooling, lack of distortion, fuel economy, ease of production and symmetry. The only advantage of the side-valve design is that of possibly more silent valve operation, and this can be largely overcome by careful design of the overhead-valve operating-mechanism. The outstanding advantage of the overhead

[2] See The Journal, April, 1922, p. 231.

type lies in cooling. In water-cooled car-engines, the overhead location usually is chosen because of the characteristically greater output, but this is really a minor consideration for an air-cooled car-engine in comparison with the marked cooling advantage. No further consideration will therefore be given to the side-valve type, beyond stating that a first-class side-valve type is much superior to a poorly cooled over-valved overhead-type.

The argument in favor of axial finning on the score that it is productive of uniform air-distribution to all parts of the barrel is basically unsound. The heat given to the cylinder-head and the barrel varies markedly throughout. Since uniform temperature-distribution is desired, it follows that this cannot be secured if the air is uniformly distributed over a surface having varying heat reception. The circumferential fin has the following advantages over the axial fin:

(1) Ease of foundry production

(2) More complete finning and cooling of the cylinder-head is obtainable

(3) A very considerable stiffening effect is obtained, counteracting any tendency of the cylinder barrel to go out-of-round

(4) With a suitable blast distribution, a very uniform distribution of the temperature throughout the head and the barrel can be secured

(5) Dirt is removed more readily from the fin cells. The axial-fin type has closed air-cells which are obtained either by bending the fin-tips or by a closely fitting jacket; both methods result in a long narrow passage from which the removal of burnt-on dust and oil or mud is a matter of some mechanical difficulty. In the circumferential-fin type, any accumulation of foreign matter is apparent on a casual inspection and is easily removed with a wire brush or compressed air

(6) The long narrow parallel air-cells of the axial-fin type are in themselves the cause of a heavy drop of pressure-head in the cooling air. The bad entry and exit from the cells, in conjunction with the sharp right-angle turns at the entry and the exit, are further causes of loss of head. From the resistance viewpoint, the easy convergence and divergence of the air at the entry to and the exit from the cells in the circumferential-fin type present a marked contrast

The normal flat-head air-cooled cylinder with axial finning betrays an appalling crudity in cylinder-head cooling. As a general rule, the head and the ports are completely bare of finning and, in nearly all cases where finning is attempted, the result is worse than a complete absence of fins, as the main results obtained appear to be the disturbance and the obstruction of the air-flow over the cylinder and a marked increase of the casting difficulties with no compensating cooling advantage. It is, however, possible to fin the cylinder crown of an axial-fin type efficiently, as regards both heat abstraction from the crown wall and dissipation to the cooling air, without causing broken or obstructed air-flow over either the crown or the barrel. Figs. 2 and 3 show two such designs by H. E. Morehouse, of the Engineering Division. These have evidence of original attack and great care, and are the first designs seen by the author that show any real attempt at head cooling of an axial-fin type. The author's admiration for these designs, however, in no way alters his belief in the superiority of the circumferential-fin type.

As regards evenness of temperature distribution in

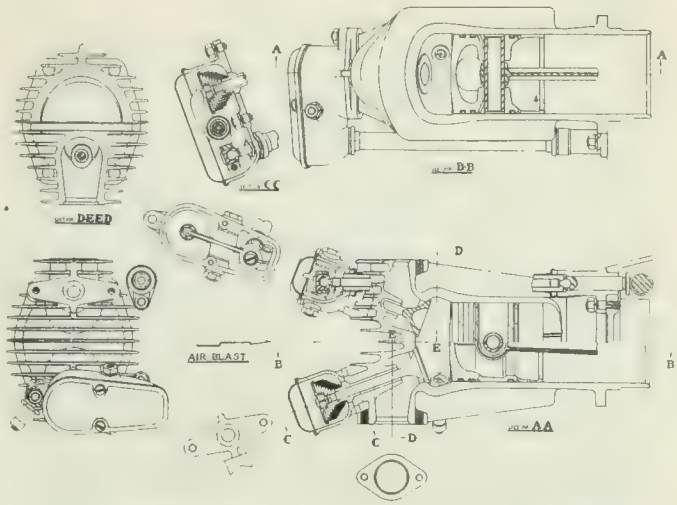


Fig. 2 The Morehouse Axial-Fin Cylinder with Horizontal Port Outlets

the circumferential-fin type, the B. S. A. car-engine cylinder, with exhaust-side blast, illustrated in Fig. 4, showed a maximum circumferential temperature-difference at full throttle of 27 deg. fahr. at the top of the barrel and 47 deg. fahr. at the base of the barrel.[3]

Form of Cylinder-Head

Recent work has confirmed the author's views still further as to the fundamental fault of the flat-head type of cylinder, and comparative tests of the types I and J Engineering-Division cylinders indicate sharply the inferiority of the flat design. Both types are of 5⅝-in. bore and 6½-in. stroke; type-I has a flat head with twin exhaust-valves and a single inlet, and type-J a hemispherical head with single inlet and exhaust-valves. These cylinders give a very fair comparison as both are by the same designer, were produced during the same period and have a common construction,[4] except for the number of valves and form of cylinder-head. The type-I, with internally cooled exhaust-valves, developed a maximum brake mean effective pressure of 132 lb. per sq. in. on a fuel-consumption of 0.62 lb. per b. hp-hr., with a maximum cylinder-head temperature of 570 deg. fahr. The type-J, with a normal exhaust-valve, developed more than 137 lb. per sq. in. brake mean effective pressure on a fuel-consumption of 0.48 lb. per b. hp-hr. with a maxi-

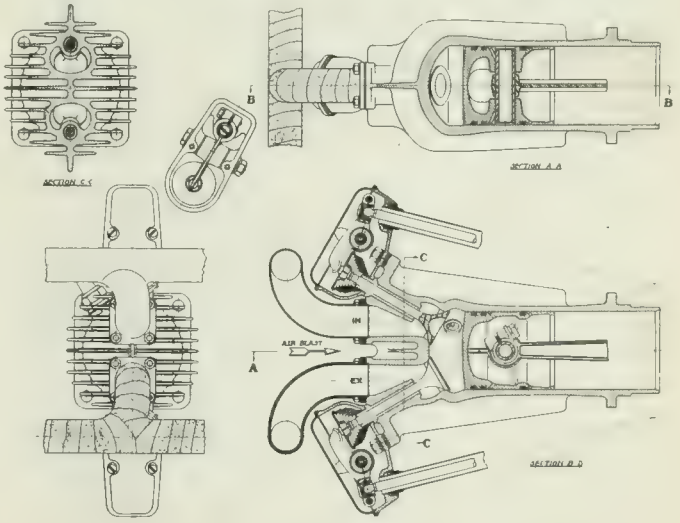


Fig. 3—The Morehouse Axial-Fin Cylinder with Vertical Port Outlets

[3] See The Journal, April, 1922, p. 231.

[4] See The Journal, April, 1922, p. 231.

mum cylinder-head temperature of 450 deg. fahr. With an internally cooled exhaust-valve, it has proved possible to run as lean as 0.43 lb. per b.hp-hr. with 123 lb. per sq. in. brake mean effective pressure.

With regard to valves, there seems to be no justification for more than two valves for any car or truck-engine cylinder. Recently, the author has had cause to modify considerably his views regarding the relative merits of two and four-valve constructions for large air-cooled cylinders. Recent experience of the Engineering Division indicates that, for up to at least 50 b.hp. per cylinder, the two-valve type is preferable on account of the less severe conditions of heat-flux in the combustion-chamber walls, fewer parts and general ease of production. Of course, the use of such power with a single exhaust-valve necessitates efficient exhaust-valve cooling. The recent work of the Engineering Division indicates that this is a matter of no great difficulty. The success of the 91 and 122-cu. in. Fiat racing cars goes to show that multi-valves are not a fundamental necessity for a maximum output, even at abnormally high speeds, and that the use of multi-valves for small cylinders in racing cars has been a matter of fashion rather than necessity.

The futility of over-valving has been demonstrated by aircraft engines of both the air and the water-cooled types. If aircraft engines, where the last pound of output is required, can secure the desired result with relatively small valves, obviously, there is no reason for the use of excessive valve-capacity in car engines where the output must of necessity be sacrificed to smooth running, acceleration and even firing at all speeds. The use of large valve-area is required only for abnormal speeds and, even in this connection, has its limits on account of the low turbulence that produces a low rate of flame propagation. For normal purposes, large valves result in a bad combustion-chamber form and an accentuation of the cylinder-head and valve-cooling difficulties.

Automobile engineers generally, and particularly those of European persuasion, seem to consider that the last step in obtaining high output has been taken by the use of large valves, apparently considering that poor torque at the lower speeds, cracked valve-seats in the cylinders and valve-burning produced by a few hours at anything approaching full throttle are necessary adjuncts to high output. Such absurdities as exhaust-valves larger than the intakes should be extinct in these days, yet they are nevertheless to be found. Even if the experimental evidence be ignored, it is difficult to imagine any logical ground for such practice when it is considered that a pressure up to 100 lb. per sq. in. is available for the expulsion of the burnt charge and only 14.7 lb. per sq. in. to produce filling with fresh charge. Therefore, it seems that such a design can only be the result of pure guesswork.

The ideal form of cylinder-head appears to be the complete hemisphere, and the more nearly this is approached the more efficient will be the design from the standpoints of minimum stress due to explosion and maximum amount of fin area directly attached to the cylinder crown. The author has found that a large angle of valve-tilt is productive of the best results, as this produces the maximum metal space between valve-ports and apparently maximum filling and discharge capacity from a given size of valve. An included angle of approximately 70 deg. between the valves has proved satisfactory, although this prohibits the direct boring of the valve-seats and ports from the cylinder mouth when an integral head and barrel are used.

The term detachable cylinder-head is used in the sense of a removable head, and not to represent the separate but non-removable head of the type shown in Fig. 1. While there is little question that air-cooled cylinders with detachable heads can be made to function with fair satisfaction, there is not much doubt that the cooling and general efficiency of the type is lower than that of the solid-head construction. Some of the reasons for avoiding detachable heads are as follows:

(1) The heat given to the head has to be almost entirely dissipated by it, as the transmission to the barrel and its finning is limited owing to the very high thermal resistance of the joint and the gasket. Hence, the head runs hotter and the barrel finning does not carry as much of the cooling duty as it might carry otherwise

(2) Gas leakage at the joint, with the attendant high temperature, is likely to occur, as the pulling-up of a gasket on a single-cylinder head is a matter of considerable skill and requires more than one adjustment

(3) The bolts or studs and their bosses for holding down the head usually cut-up the head finning considerably and break-up the uniformity of air-flow over the head

(4) The uneven sections resulting from the attachment bosses are liable to produce distortion under temperature, in addition to the mechanical distortion that is induced so readily by uneven bolting-down or lack of stiffness in the head or barrel

(5) It is easier to lift a separate cylinder for decarbonizing than to break and remake a head gasket-joint, particularly in a push-rod engine involving the readjustment of the tappet clearance after refitting the head and at intervals while the head joint is settling, as it practically always does

Satisfactory block-type cylinder-construction with air-cooling has yet to be produced and, if the detachable head be assumed to be unsatisfactory, no argument except stiffness of the engine as a whole can be adduced in its favor, as it presents an undesirable foundry problem and is more unwieldy to handle in both manufacture and service. The use of separate-cylinder construction in a water-cooled engine involves lengthening the engine by the thickness of two jacket-walls, the external space between them and the two water spaces, which, together, are usually greater than would be allowed between the barrels with block construction. These disadvantages do not apply in an air-cooled engine, as a certain minimum space for air-flow has to be allowed, irrespective of whether block or separate-cylinder construction is used.

Cylinder Material

The cast-iron cylinder with the fins cast integrally still appears to be the most logical solution for car engines up to the $2,000 class. Recent tests by the Engineering Division, which will later be dealt with more fully, have shown that, in capacities of up to 87½ cu. in. per cylinder, cast-iron cylinders at continuous full-throttle will give cooling, output and fuel economy that are adequate for automobile use.

There is a tendency to assume that some particular material can be found that will solve the difficulties of air-cooling. Design is the dominant factor in air-cooling and no material, whatever its thermal conductivity is, can counterbalance the effect of poor design. It may be well to emphasize that there is no mystery concerning air-cooling. Successful cylinder design is mainly a combination of common-sense and applied science, with very little computation involved. However, the author recommends cast iron as a cylinder material only provided a

suitable design be used. The B. S. A. car-engine cylinder-design illustrated in Fig. 4, and that of the type-K cylinder shown in Fig. 1, represent types that have proved satisfactory.

The designs already mentioned no doubt will be objected to at once for car use, on the score of the hemispherical head. This type of head unquestionably gives rise to a minor machining difficulty, but the elimination of this difficulty by the use of a flat head is sure to result in a final increase of the cost to secure a similar performance, because larger fan capacity, and probably more cowling and more expensive cylinder and valve material, will be required. While the matter has not been the subject of an exact comparative test, it is the author's considered opinion that, from the performance standpoint, the flat-head aluminum cylinder using, except for the flat head, the best of aircraft practice, is in no way superior to the hemispherical type of cast-iron head; in fact, up to 100-cu. in. capacity, it is actually inferior.

If, in the production of a medium-priced air-cooled car-engine, design be subordinated to production, the result is sure to be unsatisfactory. The air-cooled engine has yet to gain the confidence of the entire public, and it is urged that nothing be done to destroy the existing amount of faith by allowing full sway to the production engineer who can see only a production proposition in an air-cooled engine and is entirely uninterested in its functioning as a prime-mover. The Liberty aircraft-engine cylinder is an excellent example of what the production engineer can do if given a fixed piece to produce, without license to obliterate the original design to facilitate production.

It has been found that fairly thick metal is necessary in the walls and fins of a successful cast-iron cylinder. The old idea of thin walls being most efficient on account of the heat having less distance to flow through is altogether unsound in the light of present-day experience. In fact, there is considerable reason to believe that the superiority of aluminum to cast iron for large cylinders is as much due to the low resistance to heat-flow around rather than through the walls (that is, the rapid conduction of heat from the points of maximum heat-reception to the parts having a lower reception) as it is to the greater heat-dissipating powers of the fins. For a 3½-in. bore hemispherical-head cast-iron cylinder, a thickness of ⅝ in. at the center of the combustion-chamber, tapering to 7/16 in. at the edge of the chamber and to not less than ¼ in. at the lowest fin on the barrel, appears to be suitable.

Fairly thick fins are necessary to insure sufficient heat-flow capacity in average castings, ease of production and strength to resist rough handling; the last-named is by no means an unimportant factor. From these considerations, suitable fin proportions appear to be a maximum length of 1 in., a pitch not less than ⅜ in., a thickness at the root of 9/64 in. and a thickness at the tip of 5/64 in. Such fins are produced readily and commercially from stripper-plate patterns with jolt-ramming. To insure clean and sharp casting of fins having the proportions given, it appears to be necessary to have a minimum of 0.5 per cent of phosphorus in the iron.

While the straight cast-iron cylinder has a considerable advantage over more complicated and expensive and at the same time less efficient constructions commonly considered to be essential for air-cooling, it is nevertheless inferior as regards cooling, fuel economy, tendency to detonation, weight and, to a very slight extent, output, to the type of aluminum cylinder used for aircraft

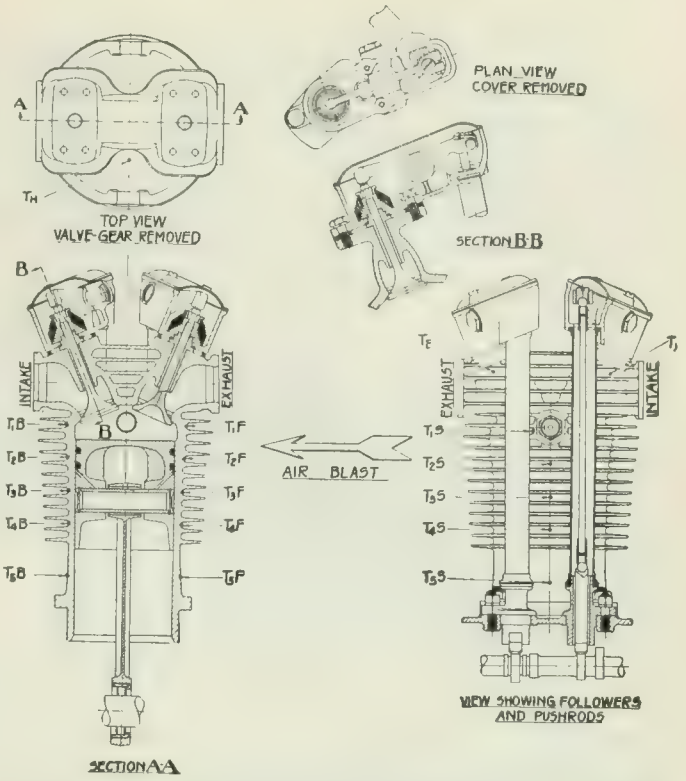


FIG. 4.—PLAN VIEW AND SECTIONAL ELEVATIONS OF THE CYLINDER USED IN THE B. S. A. PASSENGER CAR

engines. Where considerations of cost will allow, the use of aluminum cylinders should be given very serious thought. As a basis of comparison with the straight cast-iron type, the general construction used by the Engineering Division will be used. The screwed-on head aluminum-construction is the only type considered as, in general, this has proved the best all-round design for heavy duty, is the easiest type to produce and gives the least trouble with a variation of the thermal contact and the like in a quantity of cylinders. The pros and cons of the various types of aluminum-cylinder construction have been discussed at length previously.[5] The construction is well exemplified by the type-K cylinder shown in Fig. 1. The aluminum-head casting will cost more than the cast-iron, but will be much more easily machined, particularly if valves tilted to a large included angle, 70 deg. in this case, be used. The hemisphere can be machined at a much higher rate of speed, on account of cutting facility and also accessibility, as the hemispherical surface in the case of the aluminum head is not at the bottom of a deep hole. To offset the more rapid and accessible working of the interior of the head, there is the extra work due to the threading for barrel attachment, boring valve-seat insert-recesses and machining and shrinking-in the seat inserts. The seat-insert material also has to be provided; in this case it is extruded aluminum-bronze. This can be obtained extruded in tubular form, very close to the finished dimensions. While the cost of this is not negligible, a remarkably durable valve-seat is obtained and, furthermore, the inserts can be replaced with ease if damaged or worn-out, although the life is probably far in excess of that of any iron or steel seat. The aluminum head will accumulate less carbon-deposit, and the deposit obtained is more readily removable than that on cast iron. Aircraft practice at present uses forged-steel barrels with machined integral fins. The Engineering Division is, however, in-

[5] See THE JOURNAL, April, 1922, p. 231.

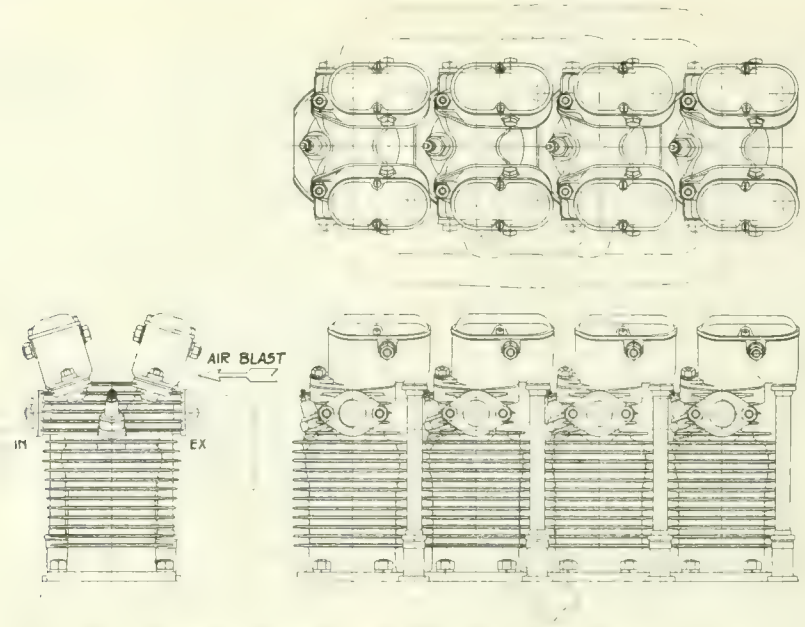


FIG. 6 PLAN VIEW AND SIDE ELEVATION OF A FOUR-CYLINDER IN-LINE ENGINE WITH THE SAME ARRANGEMENT OF PORTS AS THE ENGINE ILLUSTRATED IN FIG. 4

vestigating the possibilities of obtaining centrifugally cast steel-barrels, with little or no machining on the fins. Should this prove possible, use might be made of barrels produced in this manner for car practice. In any case, centrifugal cast-iron barrels appear to be a commercial product for car practice, as centrifugal casting produces a high-grade material having great strength, close grain, excellent wearing properties and uniform machining characteristics, with little wastage due to unsoundness. Threading the head and the barrel should not prove very costly with suitable tooling. The limits need not be excessively fine if the minimum shrink be such as to produce a slight permanent-stretch in the head. If the maximum shrink within the limits set be obtained, this will merely cause an increased stretch of the head. The general result will be to obtain a nearly uniform amount of actual shrink between the head and the barrel, irrespective of the initial shrink. The use of a separate barrel allows the replacement of this part in the event of scoring or other damage. The use of the aluminum head also causes additional expense, due to the necessity for spark-plug bushings.

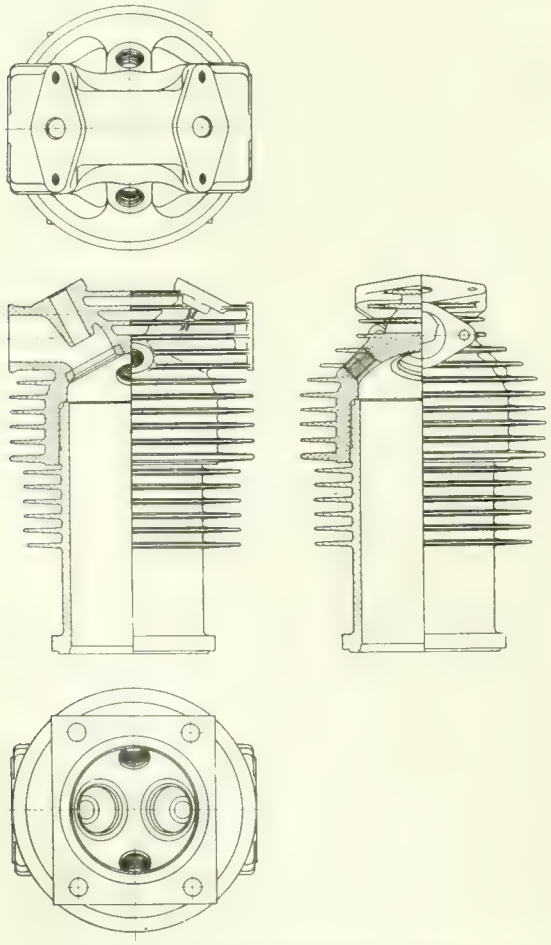


FIG. 5 A MOTORCYCLE CYLINDER WITH AN ALUMINUM HEAD SCREWED ON TO A CAST-IRON BARREL

Fig. 5 shows a successful motorcycle cylinder having an aluminum head with a screwed and shrunk cast-iron barrel. With aluminum heads, rough handling is liable to result in unscrewing the studs from the casting while removing nuts. Replacement of the valve-guides is also liable to result in torn and scored bosses, unless carried out with care. Hard alloys and the use of bronze studs go far toward minimizing the above-named troubles. In any case, the aluminum head does not suffer from the burning together of cylinder metal and studs or valve-guides that is liable to occur with cast iron.

The fin proportions recommended for cast iron are also suitable for use with aluminum. To stand rough handling, finning for car engines should generally be heavier than that used for aircraft engines, the slight increase of weight and possibly of cost being of no moment.

COOLING SURFACE

The cooling surface obtainable with finning of the proportions recommended will not vary very much. The B. S. A. cylinder of approximately 3½-in. bore and 3⅜-in. stroke has 4.18 sq. ft. of area in the fin, head, barrel and port surfaces and, at the normal maximum output of 8.5 b.hp. per cylinder, this is equivalent to almost 0.5

sq. ft. per maximum hp. The larger the cylinder is, the lower the cooling surface obtainable per unit capacity becomes and, while the smaller cylinder usually works at a higher number of revolutions per minute and has higher output per unit capacity, it nevertheless usually has greater cooling surface per maximum brake-horsepower.

The type-K cylinder has 6.68 sq. ft. of cooling surface; the head has 3.60 sq. ft. and the barrel has 3.08 sq. ft. At 110-lb. per sq. in. brake mean effective pressure and a speed of 2000 r.p.m., or 24.3 b.hp., this is equivalent to 0.275 sq. ft. per b.hp. A much higher output is obtainable from this cylinder with a cast-iron head, with satisfactory operation, although a blast velocity of 60 m.p.h. or more has to be used.

The type-J Engineering-Division cylinder has 11.40 sq. ft. of cooling surface; the head has 6.95 sq. ft. and the barrel has 4.45 sq. ft. It has a normal power of 47.5 b.hp. at 1700 r.p.m., although considerably more can be obtained without overheating; this is equivalent to 0.240

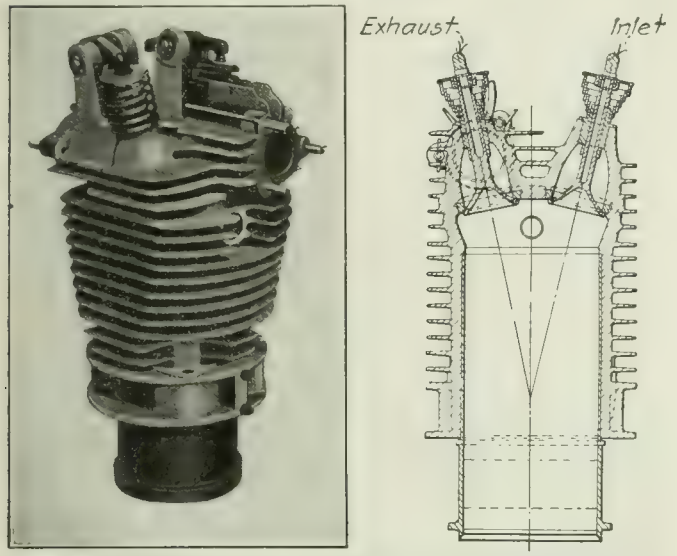


Fig. 7—Exterior View and Sectional Elevation of the 4D Cylinder Developed by the Royal Aircraft Establishment

sq. ft. per b.hp. This cylinder cools excellently at full throttle in a 70-m.p.h. blast.

The performance of the B. S. A. engine is of interest in showing the ease with which air-cooled cars with reasonable cylinder design can be cooled. This engine, of only 65-cu. in. capacity, gives satisfactory cooling on the road while pulling a car weighing 1700 lb. when loaded. It has no cooling fan, the motion of the car being relied on entirely for the cooling-air supply. An engine of such a capacity works at a considerably higher mean power-factor than do engines of capacities suitable for use in this Country. In view of this performance, the author has no hesitation in claiming that extremely efficient cooling can be obtained from any four or six-cylinder car-engine having finning of the recommended proportions and a cooling-surface allowance of 0.4 sq. ft. per maximum b.hp. This allowance, in conjunction with a suitable cooling fan that absorbs not over 3 per cent of the maximum engine brake horsepower, should give excellent cooling at continuous full-throttle on the road, provided reasonable cylinder-design and air-distribution be used.

Port-Arrangement for In-Line Engines

It is of interest to examine the possible port-arrangements with hemispherical-type cylinder-heads on in-line

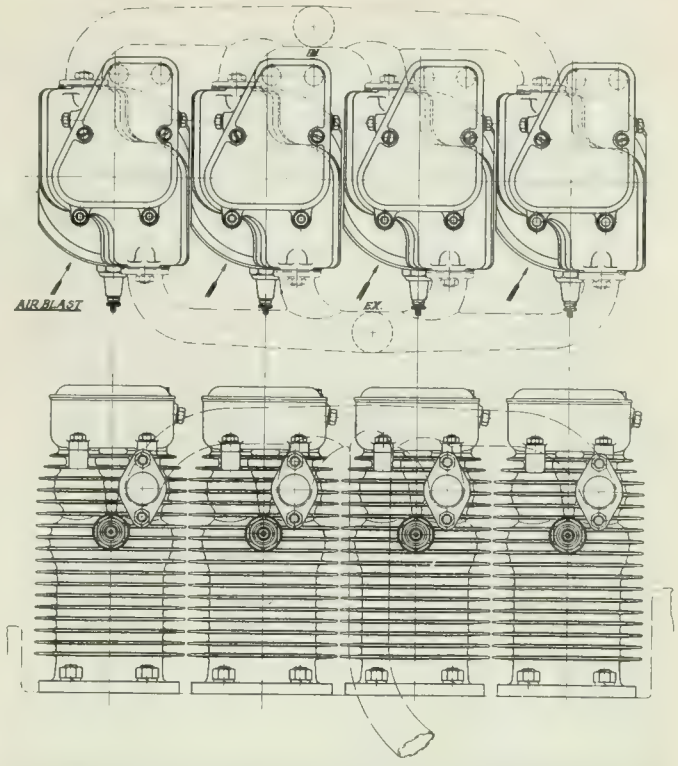


Fig. 8—Plan View and Side Elevation of a Four-Cylinder In-Line Engine with the Same Arrangement of Ports as the Engine Illustrated in Fig. 7

engines. Fig. 4 shows what is probably the best arrangement, as it allows exhaust-side draft. This type gives the most uniform cooling and results in the most readily molded cylinder casting. Fig. 6 shows a layout of a

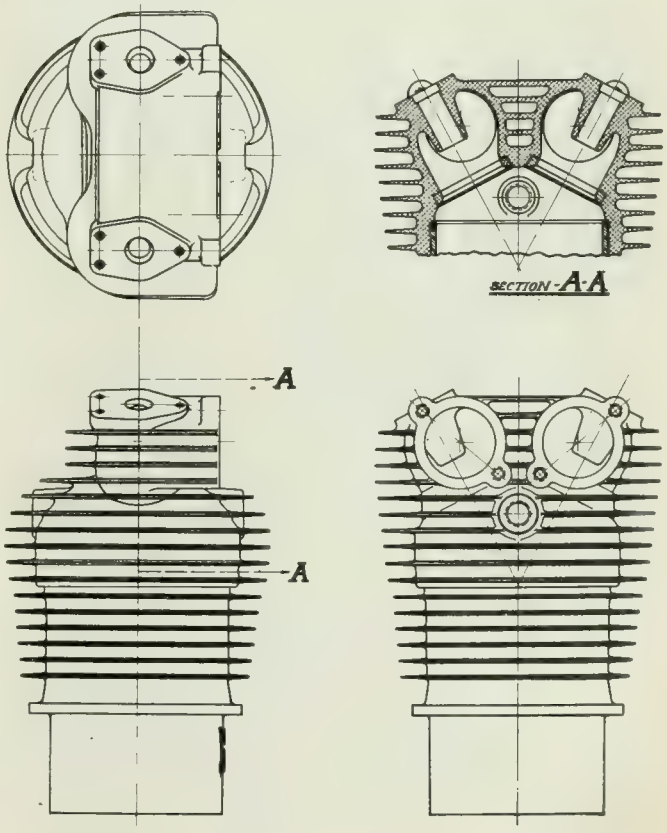


Fig. 9—Plan View, Elevations and Section of a Hemispherical-Head Cylinder with Both Port Outlets on One Side

four-cylinder in-line engine with this port-arrangement. Fig. 7 shows another possible layout; this type of cylinder has given very successful results on the R.A.E. 4D aircraft-engine. This arrangement tends to produce a longer engine than that shown in Fig. 6, as the valve-springs and the like of adjacent cylinders are liable to interfere with each other, particularly if enclosed valve-gear and valves inclined at a large angle be used. The cylinder casting in this case is not produced so readily as that shown in Fig. 6. Fig. 8 shows a four-cylinder in-line engine with the above-mentioned arrangement of porting. This type of porting does not give the best possible distribution of temperature. Fig. 9 shows yet another possible type of porting. This is used on the highly successful Armstrong-Siddeley radial air-cooled aircraft-engines. This allows the intake and exhaust-manifolds to be on the same side of the engine, which may be of advantage for hot-spotting and stoving. This type of porting has the same foundry difficulties and temperature-distribution disadvantages as that of Fig. 7. Fig. 10 shows an in-line engine with this port-arrangement.

Regarding the relative merits of the three port-arrangements illustrated, that shown in Fig. 6 is the best and those in Figs. 8 and 10 are of equal merit. It is considered that an engine with cast-iron cylinders, having ports as shown in Fig. 6, will cool and perform about as efficiently as an aluminum-cylinder engine with porting such as that shown in Figs. 8 or 10. For the best all-round design, there is little question that an aluminum engine with Fig. 6 porting is superior, as this will allow large valve inclination, permit the shortest engine and give the most efficient cooling.

Camshaft and Valve-Gear Arrangement

The port-arrangement shown in Fig. 6 necessitates two camshafts with a push-rod valve-gear or, alternatively, an overhead camshaft. The author considers that the push-rod type is by far the best for a touring-car engine, when it is considered that the advantage of the separate cylinder as regards handling, adjustment and decarbonizing is largely lost with solid-head air-cooled cylinders if an overhead camshaft be adopted. Push-rod valve-gears, to operate successfully at 3000 r.p.m. and more, can be produced with careful but not necessarily expensive design. The port layouts of Figs. 8 and 10 allow the use of a single camshaft with push-rods and practically prohibit the use of an overhead camshaft.

In settling the port and camshaft arrangement, it will be largely a question of striking an economic balance between the simpler cylinder-casting, more efficient cooling, cheaper cylinder material for equally efficient cooling, shorter engine and more expensive camshaft arrangement produced by a design similar to Fig. 6; and the more difficult castings, possibly longer engine, less efficient cooling and cheaper camshaft arrangement resulting from designs such as those shown in Figs. 8 and 10.

As regards valve-gear, the author considers that there is no possible excuse for the use of open-type gear, except that of cheapness. The open gear is noisy and wears rapidly; this gives trouble particularly with worn valve-stems and results in bad running at low speeds.

The enclosed gear, having lubricated surfaces, can be made to be extremely satisfactory. The enclosure causes the push-rods to be kept warm; the result is that the valve-tappet clearance can be maintained almost constant by the use of suitable push-rod material. An enclosed valve-gear, when using suitable push-rod material (such as aluminum, bronze or steel, depending upon the type and the material of the cylinder and the temperature attained by the rods), backed-off cams and positive lubrication, can be made remarkably silent in spite of the greater resonance of an air-cooled cylinder in comparison with a water-cooled cylinder.

The type of enclosed valve-gear shown in Figs. 1 and 4 has, in the author's experience, given considerable satisfaction. While the angles of the boxes, push-rods and rockers appear to result in complication, nevertheless the parts are really remarkably easy to produce and the difficulty of the type is mainly confined to the design office.

The lubrication of the type of valve-gear shown is satisfactorily attained by breathing through the valve-gear, vertical slots being cut in the cam-follower guides and the vapor being exhausted through a small hole in each rocker-box cover. In the B. S. A. 90-deg. V-type engine very satisfactory lubrication was obtained by breathing through the valve-gear, this being assisted by the large variation of crankcase pressure occurring during every revolution, producing a pulsation of vapor into the boxes from the crankcase and back again. Breathing through the valve-gear tends to produce an engine with an oily and dirty exterior, and allows the possible ingress of dust and grit. Direct oil-feed to the valve-gear is probably the most certain system and has decided advantages as regards valve-cooling, but it must be used with caution, as an excess of oil will result in the valves not following the cams, smoky exhaust and fouled spark-plugs.

Sleeve-Valve Types

Although the author has had no experience with the type, and while relatively little work has been done on air-cooled sleeve-valve engines, he considers that the type should be given thought. Tests by the Engineering Division on the cast-iron type-K cylinder, described under the subsequent heading of Temperature, have indicated that high wall-temperatures do not necessarily have such deleterious effects as are commonly assumed. It seems that the unquestionably high internal wall-temperatures of the sleeve-valve engine may be of no serious disadvantage, especially in view of the absence of red-hot exhaust-valves.

Temperature

The author has discussed previously, at some length, the effect of mixture-strength, compression-ratio and blast velocity and direction upon the temperature and the output.[6] Since then, however, reason for sharp modification of the views expressed has arisen.

Tests on a cast-iron head type-K cylinder such as is shown in Fig. 1 have been the cause for the modification of viewpoint. The cylinder in question is exactly as shown in Fig. 1, except that the bronze valve-seat and spark-plug inserts are omitted, and it has a cast-iron head screwed and shrunk onto the integrally finned steel-barrel. The cylinder is of 4½-in. bore and 5½-in. stroke; it has an 87.5-cu. in. capacity and an internally cooled wide-seat tulip exhaust-valve, the valve-gear being lubricated by forced feed. The best performance is a brake mean effective pressure of 140 lb. per sq. in. at 1800 r.p.m., or 28.0 hp., with a 5.3 compression-ratio and an 0.56-lb. fuel-consumption when using a mixture of 80 per cent of aviation gasoline and 20 per cent of benzol. This performance was secured with an air-temperature of 55 deg. fahr. and a head-temperature of 730 deg. fahr. at T_1, the blast speed being 100 m.p.h. It is possible

[6] See The Journal, April, 1922, p. 231.

under these conditions to run continuously on full throttle with no thermal trouble and no more detonation than is usual with an aircraft engine of high output. Not unnaturally, a cylinder having such high wall-temperatures is rather sensitive to such conditions as air-temperature and spark-advance, and it has not proved possible to duplicate regularly the output just quoted. However, it has been found possible to maintain regularly at least a brake mean effective pressure of 130 lb. per sq. in. at 1800 or 2000 r.p.m., with head-temperatures up to 800 deg. fahr. In this cylinder, the last 10 lb. of brake mean effective pressure is obtained at the cost of a very considerable increase of the head-temperature, the difference between 120 and 130 lb. causing an increase of temperature of about 150 deg. fahr.

The best performance of this cylinder was obtained under nearly ideal conditions, as an extremely large carbureter was used to secure the maximum volumetric efficiency and the maximum temperature of the exhaust-valve was about 900 deg. fahr., this temperature being confined to a very small zone. It was thought at first that the high output was due to the internally cooled exhaust-valve, eliminating the red-hot surface within the cylinder; and that, under such conditions, high combustion-chamber temperatures were of no great moment. This assumption, however, was proved incorrect by comparative tests of cooled and uncooled valves. The tests were carried out on the same day. With the cooled valve, a brake mean effective pressure of approximately 135 lb. per sq. in. was obtained; the maximum temperature of the valve-head was approximately 900 deg. fahr. and the stem was dead-black. With the uncooled valve, no change in the power or the cylinder-head temperature was evident. The uncooled valve attained a maximum temperature of about 1300 deg. fahr., which is decidedly hot. In view of the fact that the cylinder-head temperature was more than 700 deg. fahr. and that the valve was not of the best design for use without internal cooling, it was a cause of surprise that the valve-cooling was as efficient as it proved to be, especially as similar valves in many water-cooled engines run just as hot, although with cylinder-head temperatures that are probably of the order of 400 deg. fahr.

In the author's experience, cylinder-wall temperatures of the order of those attained by the type-K have hitherto invariably been associated with low output, excessive thermal trouble with the valves and the cylinder-head, detonation and a very low thermal efficiency. The type-K cast-iron cylinder has had more than 50 hr. of rather brutal full-throttle testing and, during this time, it has developed no thermal trouble beyond burnt or disintegrated spark-plugs. This cylinder attains wall-temperatures that militate against fuel economy, and the minimum fuel-consumption obtained was about 0.45 lb. per b. hp-hr., this consumption being obtained only by very delicate adjustment; it could be duplicated or bettered with much greater ease in an aluminum cylinder.

The blast direction shown in Fig. 1 is not the most suitable, and some reduction of the temperature could be obtained by the use of exhaust-side blast in conjunction with a port-arrangement similar to that in Fig. 4. The cast-iron type-K cylinder can be operated at full throttle in a blast velocity as low as 60 m.p.h. without any reduction of the output or an increase of the fuel consumption, although, of course, the head-temperature and the tendency to detonation increase.

There is no question that the cooling of this cylinder would be improved markedly if a heavy integral cast-iron barrel were used in place of the light screwed-in steel-

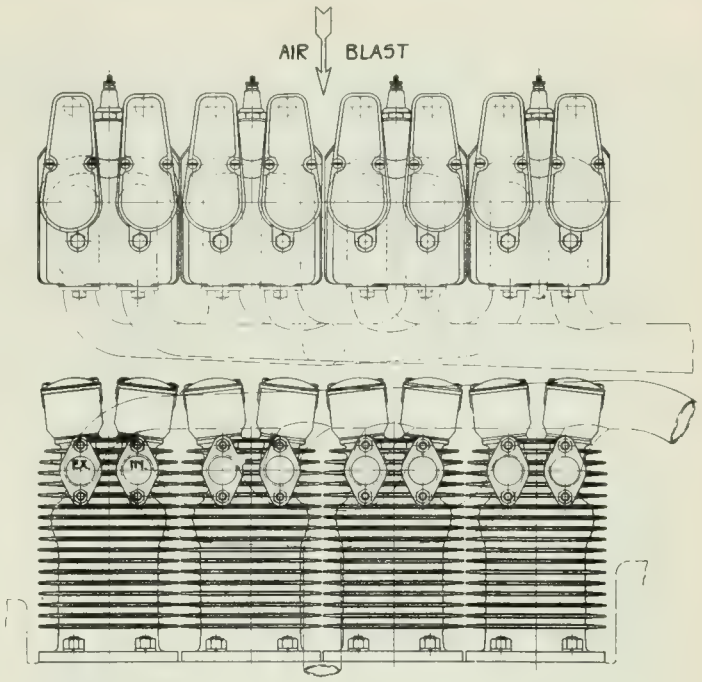


FIG. 10—PLAN VIEW AND SIDE ELEVATIONS OF A FOUR-CYLINDER IN-LINE ENGINE WITH BOTH PORT OUTLETS ON THE SAME SIDE

barrel. When choked down to a brake mean effective pressure of 105 or 110 lb. per sq. in. and arranged with a suitable blast direction and port layout, a cast-iron cylinder of even this size should give very satisfactory results in car or truck service, although such power per cylinder is hardly likely to be required. When throttled to a brake mean effective pressure of 110 lb. per sq. in., a considerable reduction in the head-temperature can be expected and excellent fuel-economy should be obtained without difficulty.

The fuel economy between three-quarter and full throttle is usually of little importance on a car or truck engine, as relatively little running is done in this range. As the effect of an increased specific fuel-consumption is to reduce the cylinder temperature markedly it is probable that beneficial results will be obtained by progressively stepping-up the consumption from 0.55 lb. at three-quarter throttle to 0.70 or 0.75 lb. at full throttle. This will tend to secure the maintenance of a constant cylinder-temperature and the elimination of detonation, and probably will not increase the fuel consumption in miles per gallon on account of permitting more full-throttle work and requiring a lower power-consumption in the cooling fan.

It is commonly said that air-cooled car-engines pick-up poorly on high-gear from low speeds. This is probably caused by charge-heating due to the hot walls, and the relatively large period available for heating at low speeds. In the author's limited experience with air-cooled car-engines, however, poor pick-up at low speeds has not proved to be a necessary evil of air-cooling. Torque at low speeds and pick-up are closely connected, and comparatively the most determined puller at low speed on high-gear that the author has had experience with was an air-cooled two-cylinder car-engine. A very probable cause for poor pick-up on air-cooled cars appears to be the very odd heavily overlapped valve-timing that is considered necessary. Such timing, while desirable for aircraft or racing engines, is not by any means suitable for a touring-car engine.

It is probable that such temperatures as are quoted

for the type-K cylinder would result in a poor pick-up. Temperatures of this order are not generally to be recommended and, in any case, would be produced only by a long full-throttle pull. They could be eliminated by shifting gears and speeding-up the engine with the throttle partly closed thus increasing the air supply and reducing the flame temperature. The average water-cooled engine of medium class is not usually remarkable for pick-up immediately after a 15 to 20-in. pull on full throttle.

In the light of present knowledge, it seems desirable for average service to limit the maximum cylinder-temperature to about 600 deg. fahr. and the mean temperature to about 350 deg. fahr., although these figures can be exceeded for short periods safely. The author is of the opinion that, if measures be taken to insure that the exhaust-valve temperature never exceeds 1000 deg. fahr., maximum and mean temperatures considerably higher than those quoted can be used without danger. In deciding how high the temperatures are to be allowed to go, it will be necessary to settle just how much the pick-up following a long full-throttle burst can be sacrificed. The use of very high cylinder-temperatures also has an undesirable influence on detonation, a factor of considerable importance with low-grade automobile-fuel.

The Engineering Division has investigated temperature conditions in the wall of a Liberty-engine cylinder and, although this investigation is still in progress, the preliminary results are of great interest for comparative purposes. The tests were conducted with full throttle at normal speed, water temperature and water circulation. With walls and jackets free of scale, the maximum temperature in the combustion-chamber wall was 310 deg. fahr. When the walls had accumulated an 0.025-in. thickness of scale, which is approximately the maximum for a Liberty-engine cylinder because flaking-off occurs on reaching this thickness owing to the deflection of the head walls, the maximum temperature rose to 430 deg. fahr. Heavily scaled cylinder and jacket-walls are the normal condition of the average water-cooled engine, scale of even ⅛ or 3/16-in. thickness being not unusual. The effect of such a coating on the wall temperature can be imagined readily if 0.025 in. is sufficient to account for a temperature-rise of 120 deg. fahr. in a Liberty engine cylinder.

The Liberty-engine tests indicate that there is probably little difference in the cylinder-wall temperature of a good air-cooled cylinder and that of a water-cooled type after it has seen some service and become scaled-up. Large aluminum aircraft-cylinders, such as the Engineering Division type-J that develops well over 40 b.hp., will run on continuous full-throttle for 8-hr. periods with maximum cylinder-head temperatures of 400 to 450 deg. fahr.

Exhaust-Valve Cooling

The design of the exhaust-valve port and seat in the average car engine, whether water or air-cooled, is extremely crude from the viewpoint of the proponent of the aircraft engine. A run of 10 hr. with full throttle at 2000 r.p.m. will work severe havoc with the exhaust-valves and seats of most car engines; whereas, in an aircraft engine, the valves will merely be nicely run-in after such a test.

Much of the barbaric practice exhibited in car-engine exhaust-valve cooling has not even the virtue of being cheaper than good design. The worst features of average practice are as follows:

(1) The width of the seat in the cylinder is usually extremely small
(2) The rim of the valve is often very thin
(3) A considerable length of the valve-stem is often directly exposed to flame
(4) The length of the valve-guide within the exhaust-port is usually directly exposed to flame, instead of being shrouded by the valve-guide boss
(5) Valve-stems of very small diameter are often used
(6) Valve-seats in water-cooled engines are rarely in direct contact with water for the entire circumference of the seat. In many air-cooled engines no attempt is made to circulate air between the intake and exhaust-ports. On the contrary, a wall of solid metal usually joins the two ports at the point of closest proximity

Taking these points in order, the disadvantages of each will be enumerated. The narrow seat referred to in (1) involves a high specific rate of heat-flow from the valve to the cylinder seat. This increases the temperature-drop from the valve to the cylinder and thus increases the valve temperature. Apparently, narrow seats are used for their rapid-seating qualities although, generally, they seem to unseat almost as quickly as they seat. Extremely wide seats have a tendency to pit slightly in excessively oily engines, on account of carbon being hammered into the face of the seat of either the valve or the cylinder, whichever be the softer.

The bad qualities of valves with ultra-thin rims, mentioned in (2), are not very readily apparent on the surface. However, consider the thermal conditions in a valve that is blowing-by in the seat, a condition that will occur more or less in service. Hot gas is blown through an aperture of small sectional-area and large exposed surface, which removes most of the available heat-content of the gas. The gas is at a high temperature and pressure and possesses an extreme cutting-quality on red-hot metal. When blowing occurs, a large volume of heat is liberated in the leak aperture. In the cylinder, this heat will flow radially, circumferentially and axially in the cylinder metal away from the location of the blow. In the valve, the heat will flow circumferentially and radially to the remainder of the valve-head. If the valve has a thin rim, there will not be sufficient heat-flow capacity to conduct the heat to the cooler portions of the valve fast enough to prevent the metal at the location of the blow being raised to the burning temperature.

With a thick valve-rim, sufficient circumferential heat-flow capacity exists to carry the heat away from the leak aperture fast enough to prevent the temperature rising locally to the erosion or burning-point. The radial heat-flow capacity does not seem to be of as much importance as the circumferential heat-flow capacity. The Engineering Division has run tulip valves with thick rims and thin centers at full-throttle for many hours under conditions of continual local-blowing, without any burning and with only the slightest of scaling. Such tests have been carried out with valves of high-tungsten steel that burn readily if the design be poor.

That rim-burning is due to insufficient capacity to conduct the heat away from the point of leakage appears to be proved by the fact that a valve that is not rotating may have a large piece burnt out of the rim, and the cylinder seat at the location of the blow will not be scaled even slightly. This is due to the fact that the heat is abstracted from the cylinder seat so fast that the temperature cannot reach even the scaling-point.

In regard to items (3) and (4), the materials section of the Engineering Division has been able to determine by micrographic examination of its structure that, in a valve operating with a bright red-hot stem, a sharp change in the character of the structure occurs at approximately the point where the stem enters the guide,

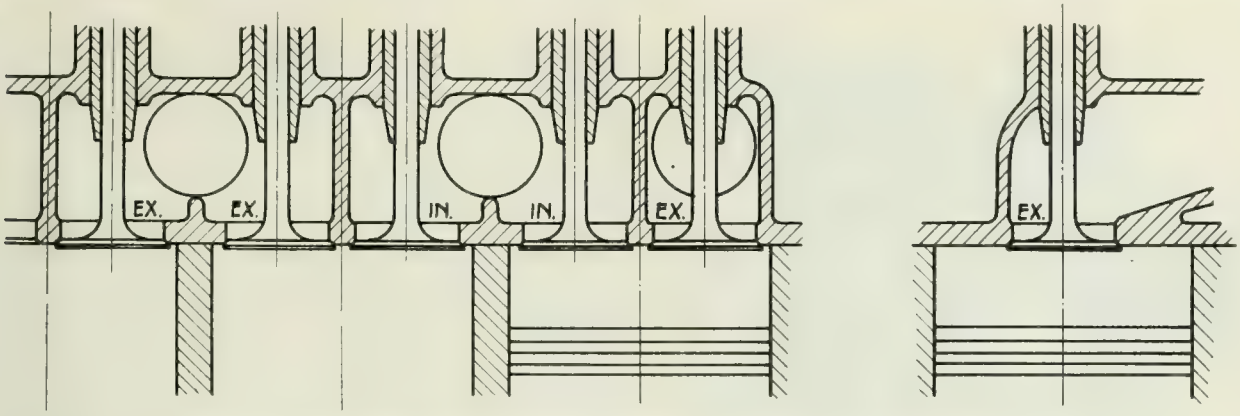


FIG. 11 -PARTIAL SECTION OF AN ENGINE ILLUSTRATING POOR VALVE-COOLING CONDITIONS

the structure showing that the portion of the stem beyond the guide has reached a much higher temperature than the section shrouded by the guide. This evidence merely confirms the conclusions of observation and experience with aircraft engines. The subject is of sufficient interest to warrant reiterating the considerations of heat-flow from the valve-stem to the cooling medium, and of heat absorption within the exhaust-port by the valve-stem, guide and guide boss.

If the whole of the section of the valve-stem within the port be beyond the guide end, the whole of the axial flow of heat from the head has to be carried by the stem which is, in addition, absorbing heat from the exhaust gases throughout its exposed length. If the whole parallel section of the stem within the port be shrouded with the exposed guide, the conditions are somewhat better, provided the guide be of sufficient thickness to be able to conduct the heat axially without reaching a red heat. The exposed guide is better than the exposed stem, as the heat-flow capacity of both the stem and the guide is available for axial heat-flow to the port wall and the guide housing. The guide, of course, presents more surface to the flame than an exposed stem, but is more able to get rid of the heat absorbed, as this only has to pass a single thermal gap in flowing to the cylinder metal; whereas the heat from the stem has to pass two. The first is a bad gap, that occasioned by the loose fit of the stem in the guide; the second is the thermal gap caused by the fit of the guide in the guide boss, which is much less serious than the former because the guide is a drive or force fit in the guide boss.

The design in which the whole of the parallel length of the stem within the port is covered by the guide, the guide in turn being completely shrouded by a fairly thick guide-boss, has proved to be the most satisfactory in full-throttle service. Heat flowing along the stem begins to be dissipated rapidly to the guide at the point where the stem enters the guide. The guide, in turn, begins to dissipate the heat to the valve-guide boss. Thus the stem, the guide and the guide boss, are available for the axial transmission of the heat to the port wall. The heat-absorption effect of the large exposed surface of a long guide-boss having relatively a large diameter seems to be of little importance, as the boss is part of the port metal and the resistance to the heat-flow is small. Theoretically a large guide-boss appears to be bad on account of causing turbulence, thereby increasing the heat absorption; but, in practice, any ill effects due to this cause are completely nullified by the improved cooling obtained.

Valve-stems of small diameter, item (5), have a low axial heat-flow capacity and insufficent surface to transmit the heat to the valve-guide. Hence, they cause a greater temperature-gradient in the stem and a higher temperature-drop from the stem to the guide than exists with large-diameter stems.

The ideal cylinder valve-seat, item (6), is symmetrical, equally cooled at all points of its circumference and of such proportions that it will not distort due to circumferential inequalities of the temperature, if such occur, or uneven temperature-distribution in other portions of the head.

The design shown in Fig. 11 exhibits the undesirable characteristics, and is of a class found in many automobile engines. It is not surprising that this type is productive of distorted valve-seats, leading to the cracking and the burning of the seat and scaled and burnt valves. This design exhibits all of the objectionable features cited and, as regards the features producing seat and guide cooling, is not appreciably cheaper to produce than that shown in Fig. 12, which illustrates an exhaust-port section of the type-K cylinder. This valve layout, while admittedly involving extreme steps to secure the valve cooling, is nevertheless worth the price involved for aircraft purposes. The valve is internally cooled, resulting in the tip of the valve-stem running at much higher temperature than it would run otherwise. The hot tip of the valve is exposed to an oil-spray. Thus, a large amount of the heat is dissipated to the oil and the direct

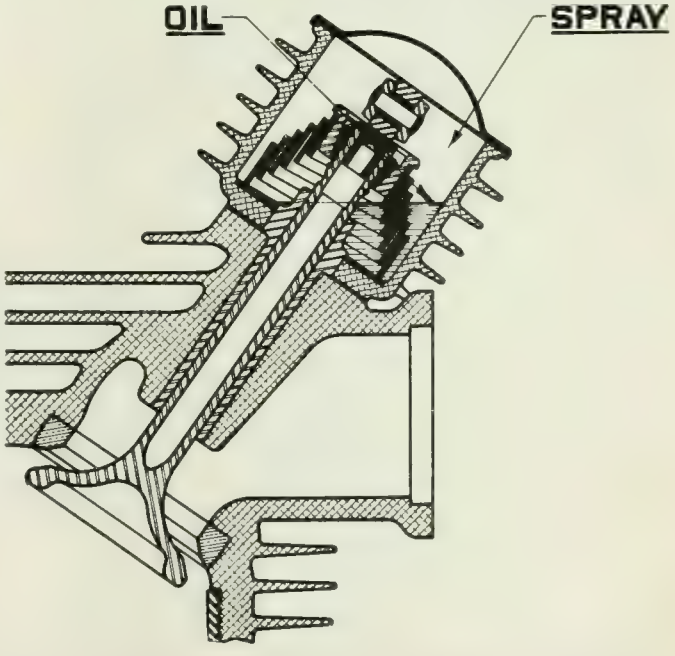


FIG. 12—SECTION OF THE TYPE-K EXHAUST-VALVE AND PORT

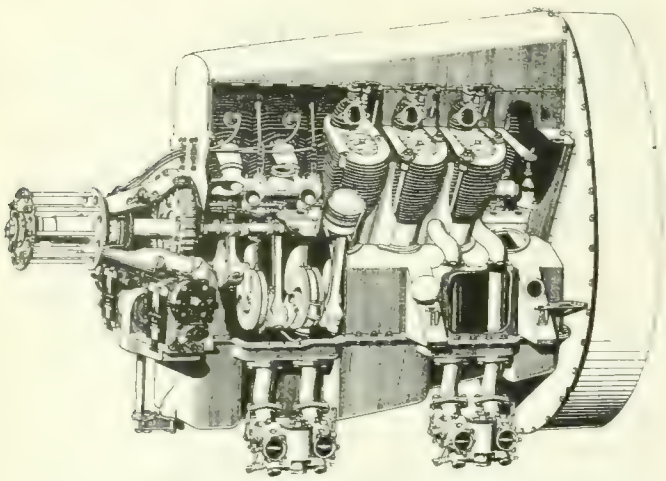


FIG. 13.—THE R.A.E. 5 ENGINE

transmission of the heat from the stem to the guide is facilitated by the oil-film between the two. This design produces a remarkably efficient valve-cooling because, on continuous full-throttle in a cast-iron cylinder, the maximum valve temperature obtained is less than 1000 deg. fahr. and this is confined to a narrow band on the neck.

AIR SUPPLY

Few successful attempts have been made at cooling in-line engines with circumferential finning. Several engines with such finning have been produced in which no effort has been made to provide uniform air-distribution; a propeller-type fan is placed at the front of the engine and blows the air onto the front of the front cylinder and down the sides of the others. While such systems may function sufficiently well to allow the engine to pass muster in flat country, the result can scarcely be called cooling and disaster is likely to result from any attempt at protracted full-throttle running in hilly country. It is commonly considered that it is next to impossible to obtain anything like an even air-supply with an in-line engine having circumferential finning. The reason for this impression is by no means clear, for, if it is possible to secure a uniform air-supply with an in-line engine with axial finning having an air-duct along the tops of the cylinders, why should it be any more difficult with an air-duct along the sides? The supposed difficulty of air supply on car engines appears to be responsible for the general lack of individuality in cylinder design in this Country. As the best-known car-engine has axial finning, the stock-design procedure appears to be a copy of this, apparently on the ground that anything else is a leap into the unknown. Since all the most successful high-duty air-cooled cylinders produced in this Country and elsewhere are of the circumferential-fin type; that is, of the Lawrance and the Engineering-Division types, the axial-fin type seems to be the more risky, for it has yet to be produced in large high-duty sizes.

Very successful cooling was obtained in the past with the Renault and R.A.E. air-cooled engines of the 8 and 12-cylinder V-type. As a V-type engine is nothing more than two in-line engines side-by-side, there appears to be little reason to anticipate any grave difficulty in securing a uniform air-supply. Fig. 13 gives a general idea of the cooling system used in the R.A.E. 5 engine, this being a copy of that previously used on the very successful Renault air-cooled V-type engines. The R.A.E. 5 engine was a 12-cylinder 60-deg. V-type having cast-iron L-head cylinders of 100-mm. (3.937 in.) bore and 140-mm. (5.112 in.) stroke, with side inlet-valves in cages and superimposed exhaust-valves seated directly in the cylinder-head. The type was used in pusher airplanes and the cooling air was supplied by a centrifugal fan at the anti-propeller end of the crankshaft. The air from the fan volute discharged directly into a vertically tapering hood enclosing the top of the V and thence discharged between the cylinders at approximately 90 deg. to the crank axis. This air-supply arrangement, assisted by the blast due to the propeller inflow and the velocity of transition, gave reasonably efficient cooling in spite of what is now known to be an exceedingly crude cylinder design. The engine complete developed 140 net b.hp. and the fan absorbed 9.25 hp. or 6.50 per cent of the engine power. The excessive power-consumption of the fan was due to the crude cylinder design, the low output and the high resistance to air-flow over the cylinder-heads. For use in tractor airplanes, the fan was omitted and the hood reversed so that it tapered down to the anti-propeller end, the front plate being omitted and the rear end of the hood and the rear of the back cylinders being blanked-off. Thus, the air supply was scooped-up by the hood and discharged between the cylinders as in the pusher type.

The foregoing should suffice to show one tried method of cooling V-type engines, and it is now proposed to deal with the cooling-air supply of in-line engines, this being the type of most general interest to the car builder.

COOLING SYSTEM FOR IN-LINE ENGINES

Fig. 14 shows a design by the Engineering Division for a cooling system for in-line engines. This design is suitable for either aircraft or mechanical-transport vehicles, but is shown adapted to a passenger-car engine. It is merely an evolution of the Renault and R.A.E. methods applied to an in-line engine. The aim in this case has been to secure an approximately uniform air-distribution to all of the cylinders without the use of a large amount of cowling and baffles, both of these having decided disadvantages in destroying accessibility and, in the case of car engines, being potential rattle and squeak sources and, in aircraft engines, causing undesirable additional weight. The design shown uses the hood or engine covering as the collector and the ducts for the cooling air and divides this into two compartments along the vertical center line of the engine. This is carried out by a vertical partition arranged so that air-flow from one side of the engine to the other is possible only through the fin-cells.

Air is collected in front through a dummy radiator, the collection being probably assisted by a fan in the case of a car engine. The air is delivered from the collector duct to the sealed pressure-compartment, suitable baffles being arranged as shown to prevent the air piling up at the rear of the compartment and thus causing the major portion of the air to flow over the rear cylinders. The pressure compartment is sealed at the rear by the dashboard and at the bottom by a sill. The air flows from the pressure compartment to the exhaust air-compartment through the fin-spaces, all air being effectively used and none wasted, and thence away to the open under the floor-boards through holes in the sill or through suitable louvers in the hood. The design is arranged so that lifting the hood leaves the engine practically as accessible for adjustment and examination as in the normal water-cooled type.

BLAST DIRECTION

It has been shown previously that the method of application of the cooling blast to a circumferentially finned cylinder has a marked effect on the maximum temperature and the temperature distribution. It is manifestly

desirable to aim at holding the temperature at the hottest part of the cylinder to a minimum, and to secure such uniformity of the temperature distribution throughout the cylinder and the combustion-chamber walls as will eliminate distortion, axial temperature-differences are not productive of distortion but circumferential differences are. This result is suitably achieved in practice by directing the cooling blast against the exhaust side of the cylinder.

Tests made on a four-valve air-cooled cylinder, the results of which are given in Table 3 of the author's previous paper,[7] showed that the maximum combustion-chamber wall-temperature with inlet-side blast was 197 deg. fahr. higher than with the blast on the exhaust side and, further, that the circumferential temperature-difference at the top of the bore was increasel from 33 deg. fahr. with exhaust-side blast to 301 deg. fahr. with inlet-side blast. Uniformity of the circumferential temperature-distribution, and thus the minimum tendency for the cylinder bore to go out-of-round, is of considerable importance in securing silence of operation, not to mention other obvious advantages.

Exhaust-side blast, as it secures the maximum effect from a given air-supply by giving the major cooling-effect of the air to the portions of the cylinder having the maximum heat-reception, thus allows a minimum air-supply. Minimum air-supply is desirable both for economy of fan-power and as regards the rapid warming-up of the engine. With large aluminum aircraft-engine cylinders, satisfactory results are obtained with the blast directed at 90 deg. to the exhaust side. However, even in aircraft practice, with aluminum cylinders and the cooling efficiency not restricted by considerations of cost, if the maximum cylinder-size and minimum air-supply are aimed at, there is no question that exhaust-side blast is desirable.

Quantity of Air

As regards the quantity of air required for cooling, much will depend upon such circumstances as the average air-temperature in the locality where the car is to be used, whether the country is flat or mountainous, or if long periods of pulling through deep sand must be provided for. The quality of the cylinder design and the efficiency with which the air is used, that is, if the maximum effect of the cooling-air supply is given to the portions of the cylinder with the maximum heat-reception, will have an influence also upon the quantity of air necessary.

A. Ludlow Clayden states that, if a water-cooled car be provided with sufficient radiator-capacity to cool at full speed and full throttle, the cooling will be sufficient normally for all other circumstances. Whether such cooling-allowance will be suitable for all circumstances with an air-cooled car is not very certain. If an air-cooled car is to be operated continuously at full speed on the level, little difficulty will be experienced in cooling without a fan. Likewise, with cylinders of the type used on the B.S.A. car, no difficulty with over-heating will arise from continuous idling with a closed hood and no fan if suitable vents be provided in the hood to allow the escape of hot air, thereby allowing natural convection. With the B.S.A. engine it was possible to idle the engine for hours on end, without having the maximum cylinder-head temperature exceed 350 deg. fahr.

For continuous full-throttle work, approximately 30 cu. ft. of air per min. per b. hp. is sufficient with correct cylinder design. It is, however, unlikely that it will be necessary to provide a fan with such a capacity for the following reasons: (*a*) the fan will have its still-air capacity considerably augmented by the motion of the car; (*b*) the average load-factor of a car engine is well below 50 per cent and, for the normally limited periods of full throttle, the heat-storage capacity of the cylinders, crankcase, oil and the like is capable of providing a heat accumulator or flywheel which, for short periods, will store heat and prevent excessive cylinder-temperatures.

While the actual heat-storage capacity per degree of temperature-rise of an air-cooled engine is considerably lower than that of a water-cooled engine, the effective capacity is probably fully as great, due to the fact that the heat can be stored at a much higher temperature; while heat storage ceases in a water-cooled engine when boiling commences, no such critical temperature exists with an air-cooled type. To what extent the heat-storage capacity effect can be used is open to some doubt. The Engineering Division has had reason lately to modify its view in this respect, due to work on cast-iron cylinders.

Gibson has determined the characteristics of heat dissipation from finned cylinders in the wind-channel, and from actual engines found the relation between the speed of rotation and the air discharge from the fan and the cowling; he presents these data in his paper on The Air Cooling of Petrol Engines.[8] The results of these findings are as follows:

(1) The heat dissipation is proportional to the difference between the mean temperature of the cooling surfaces and that of the incoming air

(2) The heat dissipation is proportional to the 0.73 power of the weight of cooling air brought into

[7] See The Journal, April, 1922, p. 236.

[8] See *Proceedings of the Institution of Automobile Engineers*, vol. 14, p. 243.

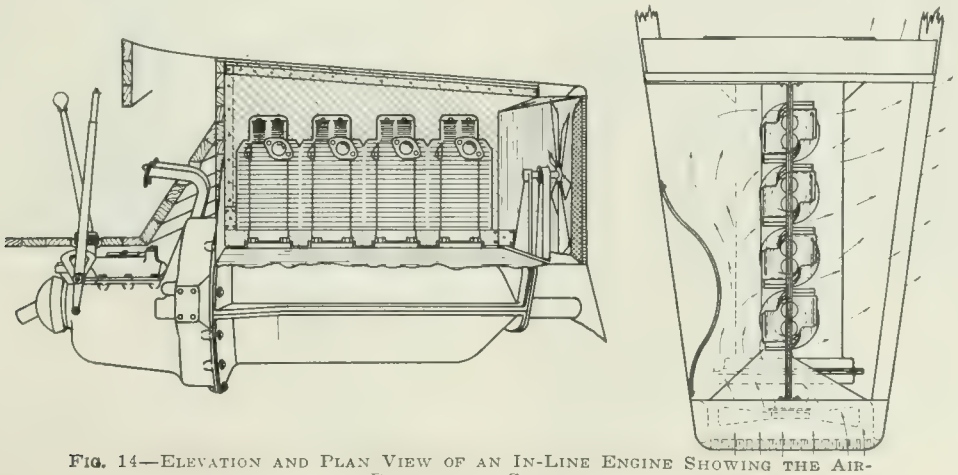


Fig. 14—Elevation and Plan View of an In-Line Engine Showing the Air-Distribution System

contact with the cooling surfaces per unit of time. For a pressure type of fan, this sensibly equals $V^{0.73}$, where V is the velocity of the cooling blast

(3) The discharge of a cooling fan of the propeller or centrifugal type, moving air through a cooling system of the type shown in Fig. 13, is approximately proportional to $N^{0.85}$, where N is the number of revolutions per unit of time

Thus, as the heat dissipated at a constant mean-temperature is proportional to $V^{0.73}$ and V varies as $N^{0.85}$, the heat dissipated will, at constant mean-temperature, vary as $(N^{0.85})^{0.73}$ or $N^{0.62}$.

Assuming that the mean effective pressure and heat loss per brake horsepower do not vary with the speed of rotation and, therefore, that the heat to be dissipated is proportional to the speed, or N, a fan-cooled engine will get hotter with an increase of the speed of rotation, since the heat to be dissipated will increase as N but the cooling effect at a constant mean-temperature will increase only as $N^{0.62}$. Under these conditions the following will hold:

Let

C = a constant
C = a constant
C = a constant
N = the number of revolutions per unit time
T = the mean temperature-difference between the cooling surfaces and the incoming air
V = the velocity of the cooling blast

Then we have

Heat given $= C_1N$

Heat dissipated $= C_2V^{0.73} \times T = C_3N^{0.62} \times T$

Since the heat given equals the heat dissipated, we have

$$C_1N = C_3N^{0.62} \times T$$

$$T = \frac{C_1N}{C_3N^{0.62}} = CN^{0.38}$$

From the equation deduced with the stated conditions, the effect of doubling the speed of rotation of a fan-cooled engine at full throttle, when the fan capacity is not assisted by the car motion, will be to increase the mean temperature by 30 per cent. Actually, of course, the mean effective pressure falls off at the higher speeds; thus, the heat to be dissipated does not increase so fast as the engine speed. Further, the cylinder-wall temperature at the point of maximum temperature, even with a sensibly constant brake mean effective pressure and a constant air-supply, does not increase in direct proportion with the speed, or approximately with the output. This is of importance because, with sound cylinder-design, the maximum rather than the mean temperature appears to be the limiting factor in operation.

Table 1 shows the results of some tests made by the author on a four-valve air-cooled cylinder of $5\frac{1}{2}$-in. bore and 6-in. stroke. Reference is made also to Figs. 1 and 9 and Table 10 of his previous paper.* These tests were carried out with a constant air-blast velocity of 87 m. p. h. The temperatures given are those at the hottest point of the combustion-chamber wall, and it will be seen, from the ratio of the temperature to the brake horsepower, that the temperature does not increase proportionally to the output. The temperature increase with the speed was in this case greater than occurs with normal design, owing to the restricted exhaust capacity that resulted in the maximum heat-reception by the point least able to dissipate the heat received; that is, the bridge between the two exhaust-valves.

The figures in Table 1 suggest that a fan-cooled engine with an air-supply proportional to the engine speed to a fractional power less than 1, and arranged so as to keep the maximum cylinder-temperature around 400 deg.

* See THE JOURNAL, April 1923, pp. 283, 287 and 297.

TABLE 1—ENGINE TESTS

Speed, R.P.M.	Power, B.Hp.	Brake Mean Effective Pressure, Lb. per Sq. In.	Fuel-Consumption, Lb. per B.Hp-Hr.	Difference between Cylinder-Head Temperature and Air Temperature, Deg. Fahr.	Ratio, Temperature to Brake-Horsepower	Per Cent
1,200	25.4	117.5	0.61	389	15.3	100
1,400	31.0	123.0	0.60	407	13.1	86
1,600	36.9	128.0	0.57	450	12.2	80
1,700	39.5	129.0	0.56	452	11.4	75
1,800	40.9	126.0	0.56	462	11.3	74
1,900	42.1	123.0	0.56	463	11.0	72
2,000	43.1	119.5	0.56	515	12.0	79

fahr. with full throttle at normal engine-speed, will not develop excessive cylinder-temperatures at full speed and full throttle. This is in view of the Engineering Division's experience that temperatures hitherto considered excessive can be used without damage, reduction of output or unsatisfactory performance.

To arrive at the quantity of air required for cooling, it is proposed to use a hypothetical design of a six-cylinder car-engine, using a known cylinder arranged on a crankcase in a manner that past experience indicates fairly definitely will produce satisfactory cooling with the air-supply and output assumed. The B.S.A. cylinder has been taken as a basis, the design being modified to suit an in-line engine, the fins being slabbed off to be 11/16 in. long on the sides at the base of the barrel, a 1/16-in. space between the fin-tips being allowed. Two cylinders are shown arranged thus in Fig. 15 and, if all the air used be forced through the fin-cells, the area available for flow is 8.6 sq. in. The bore is $3\frac{1}{2}$ in. and the stroke $3\frac{3}{8}$ in., giving a capacity for six cylinders of 195 cu. in. The output is assumed to be 100-lb. per sq. in. brake mean effective pressure at 2500 r.p.m., or 61.5 b. hp., and the blast velocity 60 m.p.h., or 5280 ft. per min., at the throat as shown by the black area in Fig. 15.

The total air-flow under these conditions becomes $[(8.6 \times 6)/144] \times 5280 = 1890$ cu. ft. per min.; and this figure equals 30.8 cu. ft. per min. per b. hp. The theoretical power necessary to move this quantity of air at 60 m.p.h. is 0.52 hp. It will, however, be of more interest to calculate the power required from the pressures found necessary on engines that have been poorly laid-out.

The R.A.E. 5 engine shown in Fig. 13, which had an excessive pressure-drop in the air-flow around the cylinders, required a total head of 6 in. of water. The static plus the velocity head, in the cowl to produce approximately the 60-m.p.h. blast between the cylinders that was necessary to secure good cooling at continuous full-throttle on the dynamometer. A total head of 6 in. of water will therefore be assumed, although this is probably at least 50 per cent in excess of that necessary. By extrapolation of the tables given in Kent's Mechanical Engineers' Pocket-Book for the American Blower Co.'s Sirocco fans, the power required to force 1890 cu. ft. of air with a total head of 6 in. or water is 3.1 hp. or 5 per cent of the maximum engine-output.

Assuming that the discharge of the fan varies as $N^{0.85}$ and that the power consumed is proportional to the cube of the discharge, the power absorbed will be proportional to $(N^{0.85})^3$ or $N^{2.55}$. If 3.1 hp. is absorbed at 2500 r.p.m., at 1250 r.p.m. only 0.53 hp. or 1.70 per cent of the full-throttle horsepower at this speed, assuming 100 lb. per

sq. in. brake mean effective pressure, will be absorbed. But 1.7 per cent of the full-throttle output is equivalent to only 1.7 lb. per sq. in. friction mean effective pressure, a power loss that is negligible in comparison with the other losses, especially when it is considered that the fan and water-pump losses of the normal water-cooled engine are replaced by the above loss. It is easily possible to produce an extrafriction-loss of three or more times the order of 1.7 lb. per sq. in. mean effective pressure by having the oil too cold or too heavy.

Objection may be raised to the above-given computations as being hypothetical. However, as good cooling with similar blast-velocities and cylinder-spacing has been obtained with aircraft engines and, as the output assumed has actually been obtained with this cylinder, although without the fins slabbed-off but with a lower cooling-blast velocity, the whole appears not to be wild assumption.

The B.S.A. cylinder is not of the most useful proportions for use on an in-line engine, as the bore-stroke ratio used will produce a relatively long engine. However, no difficulty would arise in using a cylinder of about 3-in. bore and 5-in. stroke in a similar manner. The hypothetical design considered would be capable of continuous full-throttle at the speed quoted and, since the air was considered as being supplied without assistance from the motion of the car, there is no question that the engine would be grossly over-cooled in normal passenger-car service.

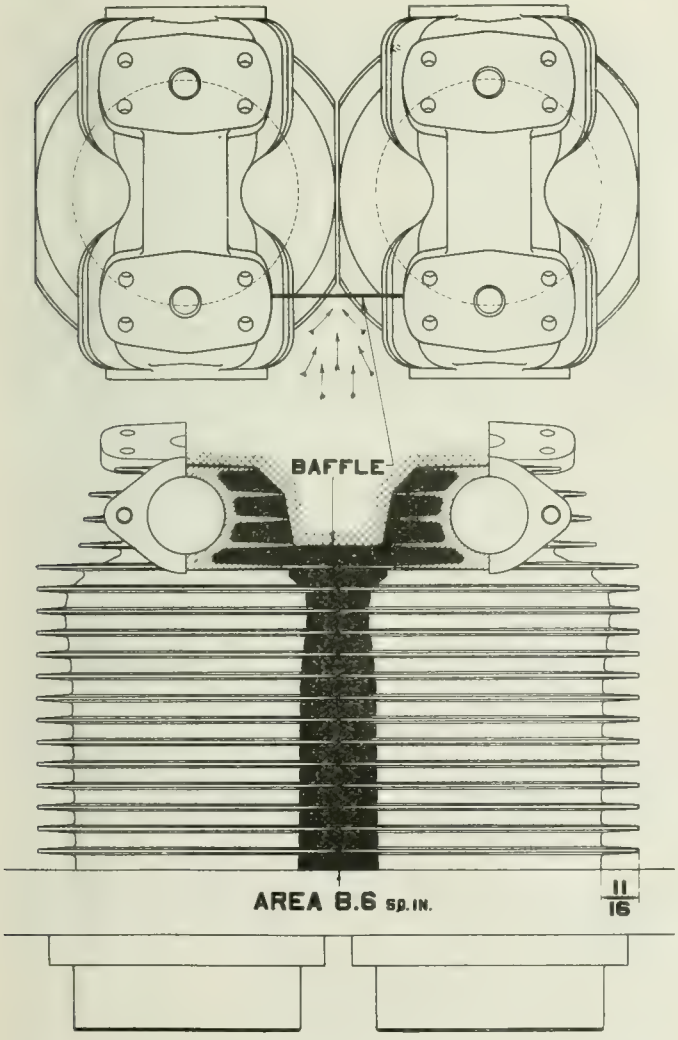


FIG. 15—DRAWING SHOWING THE AREA AVAILABLE FOR AIR-FLOW BETWEEN IN-LINE ENGINE CYLINDERS

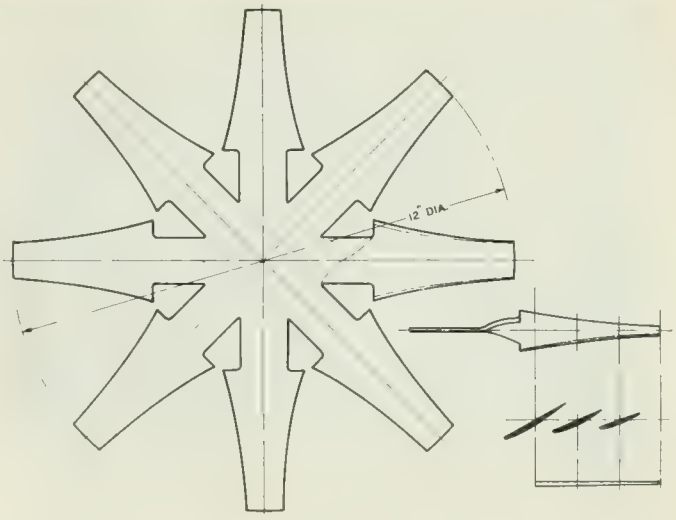


FIG. 16—DRAWING OF BLOWER DEVELOPED BY THE ENGINEERING DIVISION

FANS

The pressure type of fan is decidedly more efficient for cooling than the suction type, for the turbulent discharge of the pressure type is much more effective for heat abstraction than the approximately streamline flow induced by the suction type. Further, with the suction type at a given fan-speed, the hotter the engine becomes, the lower the weight of air passing over the cylinders will be, the discharge of this type falling much more rapidly under such conditions than that of the pressure type.

The use of an exhaust turbine-driven cooling-fan has been proposed. While this would doubtless be very expensive and difficult to produce, it would be nearly ideal in that the air-supply would be almost directly proportional to the indicated horsepower developed at any moment and would further provide a very efficient muffler, although the fan itself would be liable to scream on account of the high rotational speed necessary.

As regards the choice of the fan type, whether propeller or centrifugal, much will depend upon the service required. For a truck or tractor engine that must be capable of developing continuous full-power at very low vehicle-speeds, there is little question that the centrifugal type is the best, since it handles large volumes of air with a relatively high discharge-pressure at a fairly low number of revolutions per minute and is relatively very quiet.

For passenger-car use, there is much to be said in favor of the propeller type of fan because it can be used in the conventional position, is easy to drive, has, when properly designed, a very high efficiency, does not require any elaborate casing to secure efficiency and, when suitably installed in a phaeton, will have its still-air capacity very considerably augmented by the motion of the car. The propeller type is, however, noisier than the centrifugal type and, when running at very high speeds, is liable to produce an objectionable whine. The propeller type, unless of large diameter or run at very high speed, does not give as high a discharge pressure as the centrifugal type, and is therefore not so suitable where cooling is required at continuous full-power with a slowly moving vehicle.

If a propeller type of fan be used, care will be neces-

sary in the design of the cooling system to keep the friction-head of the cowling, the fin-cells and the ducts to a minimum. There is little question that a propeller type of fan would be of small use with an axial fin-construction having long narrow cooling-cells with a large friction-head. With a centrifugal fan, a high friction-head in the cooling system can be overcome by an increased fan-power, bad though this may be. With the propeller type, however, a high friction-head will result in little or no air-flow. Some propeller-type blowers recently designed and produced by the propeller branch of the Engineering Division are of considerable interest from the air-cooled passenger-car engine point of view. One of these blowers is illustrated in Fig. 16. This blower runs at 4000 r.p.m., has a delivery of 2000 cu. ft. per min. against 0.85 in. of water pressure, absorbs 0.36 hp. and shows an efficiency of 74 per cent. This particular point on the delivery curve was chosen because it is considered to be the most suitable one for an air-cooled car operating at full speed and full throttle. While the discharge pressure of this fan is not very high, it must be considered that, at high speeds, the head will be considerably augmented by the velocity of transition of the car. A blower of the type shown is in a very different class from that of the wind-churns fitted to the average water-cooled car. The average fan fitted is extremely inefficient and not appreciably cheaper than the one shown in Fig. 16. Fans absorbing 6 hp. at the maximum engine-speed are by no means unknown on water-cooled cars. A power consumption of this order constitutes a serious wastage without adequate return.

Fuel

Probably owing to the fact that their mean wall-temperatures are normally somewhat higher, an air-cooled cylinder seems to require fuel with less tendency to detonate than does a water-cooled engine of similar size and compression-ratio. The difference is not very marked and, in any case, it is probable that detonation is apparently more acute in the air-cooled type than in a similar water-cooled cylinder, due to the fact that the noise is not deadened by the equivalent of a water-jacket. However, the air-cooled engine is not damaged by detonation to anything like the extent that the water-cooled type is. The Engineering Division has run air-cooled cylinders for extended periods of full throttle with violent ringing pinking occurring every second or third explosion without apparent damage to the cylinder and with only slight distress from the spark-plugs. Such treatment of a water-cooled cylinder will result usually in exhaust-valve, spark-plug and piston trouble.

Spark-Plugs

The Engineering Division has had no great difficulty in securing spark-plugs capable of standing-up to sustained full-throttle in air-cooled engines. Plugs of both mica and porcelain construction have given satisfaction, and there seems to be no ground for the notion that highly elaborate and expensive plugs are essential or that over-heated and burnt-out plugs are a necessary adjunct of an air-cooled engine. Plugs capable of standing more than 100 hr. of full-throttle running without apparent deterioration have been obtained by the Division. These plugs are not of a type designed only to withstand heat, but have considerable resistance to fouling in addition to being able to withstand unlimited full-throttle running.

[10] Contributed by C. Fayette Taylor, S.M.S.A.E.—Engineer in charge of powerplant laboratory, engineering division, Air Service, McCook Field, Dayton, Ohio.

Pistons

The use of piston material other than aluminum, and possibly magnesium alloys in the future, for air-cooled car engines is not worthy of consideration, as the effect of the aluminum piston, in comparison with cast iron or steel, is to secure an increase of output, a lower fuel-consumption, a higher allowable compression, less tendency to detonation and a better pick-up, particularly at low speeds. Any company that is incapable of successfully using aluminum pistons would be well advised to leave air-cooled cars alone. There is no reason to anticipate piston trouble with air-cooled engines. The Engineering Division has had much less burnt piston trouble with air-cooled than with water-cooled engines. In fact, anything other than the very slightest of pitting has yet to be experienced, in spite of several hundreds of hours of full-throttle testing with cylinders of 5½-in. and larger bore.

Collapsed and severely pitted pistons are by no means unknown with the modern high-efficiency water-cooled aircraft-engine, and just why this should not occur also with air-cooled engines of similar duty and output is not clear; nevertheless, such is the case. It is possible that the lack of piston trouble in the air-cooled aircraft-engines is due to the more careful general thermal design of the whole cylinder-unit that has had to be developed to make a cylinder of high output function at all.

Conclusion

While, from the automobile standpoint, the paper may seem to deal too largely with large-capacity cylinders and full-throttle conditions, nevertheless the following reasons justify such considerations. First, scaling-down of design in internal-combustion engine cylinders is a safe process, while scaling-up is decidedly unsound. The dangers of scaling-up would be speedily evident if an attempt were made to use the type of cylinder design generally found in air-cooled vehicles, for 150-cu. in. aircraft-engine cylinders. The use of scaled-down successful aircraft practice has, in general, proved mechanically and thermally satisfactory. Much of the so-called aircraft practice grafted onto post-war car-design has been the work of designers lacking in experience with successful modern aircraft engines. A considerable amount of the practice can rightly be described as aircraft design, with the qualifying statement that it was proved unsound for aircraft use and was discarded during 1914 and 1915. Second, as thermal troubles have been the greatest cause of difficulty with air-cooled cars, a consideration of the designs capable of continuous full-throttle running is likely to demonstrate the ease with which the relatively mild thermal difficulties of an air-cooled car can be overcome.

The preparation of this paper has been greatly assisted by the able work of H. E. Morehouse in preparing many of the designs illustrated and by the very practical automobile viewpoint of L. H. Pomeroy who has enabled the author to grasp more clearly the essential differences in the duty of automobile and aircraft engines.

The appendices by Messrs. Dix and Taylor should tend to give the contribution a less biased character, for these gentlemen are thoroughly familiar with the vices and virtues of both air and water-cooling, in their own fields of effort.

APPENDIX 1

Experimental Development of Air-Cooled Engine-Cylinders[10]

In connection with Mr. Heron's paper, it is of interest to review briefly the methods used by the Engineering

Division in developing and testing cylinder units for both air and water-cooled engines, and to discuss some of the results obtained with several of the air-cooled cylinders mentioned by Mr. Heron. In general, nearly all the conclusions reached in Mr. Heron's paper regarding the performance of air-cooled cylinders have been confirmed by work in the Engineering-Division laboratories. In those few cases where tests have not been made by the Engineering Division, the information given is based on tests made by the Royal Aircraft Establishment of Great Britain.

All cylinder units developed by the Engineering Division are tested on an apparatus known as a universal-test engine. This consists of a ruggedly built single-cylinder crankcase arranged so as to accommodate any of the usual sizes of aircraft-engine cylinder with any valve-gear, of either the push-rod or the overhead type. The crankcase is equipped with a chankshaft having an adjustable stroke, and with means whereby the compression-ratio of the cylinder can be changed readily. The lubrication system of the engine is arranged so that the oil is circulated through temperature-control apparatus, by which any desired temperature of the lubricating oil can be maintained. Means are provided also for adjusting the rate of flow of the lubricating oil through the bearings and the crankpin of the engine and for regulating, within limits, the amount of oil sprayed into the cylinder.

The universal-test engines, several of which are available at the Engineering Division laboratories, are direct-connected to 50-hp. Sprague electric dynamometers of the usual type. Fig. 17 shows an installation especially designed for testing air-cooled cylinders. The cooling-air is supplied by a 100-hp. centrifugal-blower delivering air through a duct 18 in. square at velocities up to 120 m.p.h. The blower is arranged so that the blast can be applied against the cylinder in a direction either parallel or perpendicular to the crankshaft axis. The fuel-consumption is measured by accurately graduated special volume-meters. Stop-watches are used to time the flow of fuel through the meters. Load scales, speed-counters, thermometers, air-speed meters and the like, are installed carefully and calibrated at regular intervals. Cylinder temperatures are obtained from thermocouples that are embedded in the cylinder-walls.

In testing an experimental cylinder-design, at least two cylinders are built, since it has been found that results obtained on only one cylinder of a type are apt to require verification. Great care is exercised in "working in" cylinders for test, to make sure that the pistons, piston-rings, valves and valve gear are thoroughly worn-in and that the cylinder castings are well seasoned. This eliminates a frequent source of error in testing new cylinders. Considerable importance is attached also to the determination of the proper carbureter and venturi size for a given cylinder. While it is possible to estimate these sizes closely, a series of runs with different sizes is made, where any doubt exists, to establish the proper conditions in the induction system.

PERFORMANCE INVESTIGATIONS

In making a thorough investigation of the performance of an experimental cylinder, the necessity of changing the mixture-ratio and the timing of the ignition, to suit varying conditions, is realized fully. When investigating the performance of a cylinder at any given speed, the first run usually made is one in which the amount of fuel supplied to the cylinder is varied and all other conditions are held constant, except that the timing of the

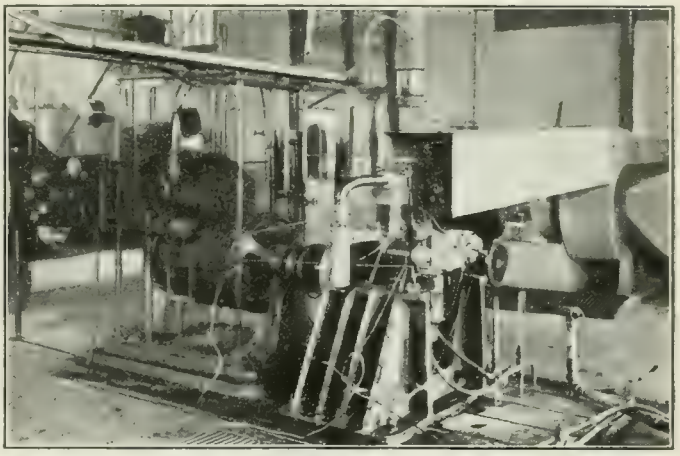


FIG. 17—INSTALLATION OF THE SINGLE-CYLINDER TEST APPARATUS USED BY THE ENGINEERING DIVISION

spark must be set to the optimum position for the particular mixture-ratio used. Curves of typical runs of this kind are shown and will be discussed in greater detail later. Such curves are extremely convenient in determining the proper carbureter and ignition settings for a certain cylinder at any given speed. In the case of air-cooled cylinders where the performance of the cylinder is so closely connected with the amount of fuel supplied, tests of this kind are of primary importance.

One particularly difficult problem in single-cylinder development is that of making proper allowance for the friction losses on the single-cylinder engine. To predict accurately the performance of a multi-cylinder engine from the single-cylinder tests, it is necessary to determine as closely as possible the friction losses of the single-cylinder engine. Unfortunately, no direct method of measuring friction losses during actual engine operation exists at present. The following methods for obtaining an approximation of the friction losses are available:

(1) The engine can be driven by the dynamometer at various speeds, holding the oil temperature, as well as the water temperature in the case of a water-cooled cylinder, at the same value that is used in the running tests and observing the power required to drive the engine at various speeds. This method is open to the objection that the piston and the bearing pressures are not equal to those that exist during the firing stroke, and that the cylinder is not running at its normal working-temperature. The difference in the bearing pressures would tend to make the readings thus obtained too low, while the lower cylinder-temperatures would tend to make them higher than during normal operation. It is probable that this latter effect is the more important, and that the friction losses so obtained are slightly higher than those actually existing when the engine is running

(2) The engine can be run under normal conditions at a given speed until the conditions are steady, the ignition and air-blast then being suddenly switched-off and the dynamometer operated as a motor. As soon as possible after this shift is made, a number of readings of the friction load are taken at regular intervals of time, measured from the instant at which the engine ceased to fire. The results are plotted in terms of friction load versus time, which gives a curve that can be extrapolated to the point of zero time, the intersection being the desired friction-load. This method attempts to take account of the normal operating-temperatures

TABLE 2—FRICTION LOSSES; DETERMINED ON THE UNIVERSAL-TEST ENGINE[11]

Cylinder-Type Designation	Speed r.p.m.	Universal[12]	K	W-1	H	W-2	L	Cast-Iron Head	J	S
Bore, in			4½	5½	5½	6½	5	5	5⅝	5½
Stroke, in			5½	6½	6½	7½	7	6	6½	6½
Type of Cooling			Air	Water	Air	Water	Water	Water	Air	Air
Compression-Ratio			5 32	5 40	5 40	5 43	5 42	5 38	5 30	5 21
Total Friction, hp	1,600	2 75	5 20	9 00	6 40	13 10	8 30	7 20	9 00	8 00
	1,700	3 00	5 82	10 00	7 40	15 30	9 00	7 85	10 00	8 90
	1,800	3 20	6 48	11 00	8 50	18 00	9 80	8 50		9 90
Friction Mean Effective Pressure, lb. per sq. in.	1,600		29 40	28 70	20 40	26 00	29 80	30 20	27 50	25 50
	1,700		31 00	30 00	22 20	28 60	30 40	31 00	28 70	26 70
	1,800		32 60	31 20	24 20	31 80	31 30	31 70		28 10
Total Friction without Crankshaft and Auxiliaries, hp	1,600		2 45	6 25	3 65	10 35	5 55	4 45	6 25	5 25
	1,700		2 82	7 00	4 40	12 30	6 00	4 85	7 00	5 90
	1,800		3 28	7 80	5 30	14 80	6 60	5 30		6.70
Friction Mean Effective Pressure without Losses of Crankshaft and Auxiliaries, lb. per sq. in.	1,600		13 85	19 92	11 64	20 60	19 95	18 65	19 10	16 75
	1,700		15 00	21 00	13 20	23 10	20 30	19 25	20 10	17 70
	1,800		16 48	22 10	15 00	26 20	21 10	19 75		19 00

[11] Different cylinders used, of types designated.

[12] Inclusive of crankshaft and auxiliaries.

of the engine but, in case of the universal-test engines, it gives results very nearly the same as are obtained by method (1)

(3) The indicated horsepower can be obtained by a suitable indicator and the friction losses computed by subtraction of the brake horsepower. This is obviously the most desirable method but, unfortunately, the Engineering Division has not yet discovered an indicator that is sufficiently accurate for this purpose at the high speeds at which aviation engines are run. It is to be hoped that such an instrument will be developed in the near future

Method (1) is generally used by the Engineering Division, since it is very convenient and appears to be as accurate as any of the methods available. Several independent investigators have stated that the results obtained by this method are very close approximations of the friction losses that exist under actual running conditions.

Table 2 shows the friction losses of the universal-test-engine crankshaft and auxiliaries, which are practically the same irrespective of the type or the size of the cylinder. Table 2 also shows the friction losses of a number of different types of cylinder on the engine, both including and excluding these losses. For comparing the performance of different types and sizes of cylinder, the writer prefers to add the power lost in friction of the basic engine, that of the crankshaft and the auxiliaries, to the brake power-output of the engine with each cylinder, and to correct the performance data to the values so obtained. While this method gives better performance-figures than can be obtained normally in multi-cylinder engines, it is useful for comparative purposes, and the absolute values so obtained are a measure of a cylinder's potential output since only those losses inherent in the cylinder design are included; those losses that depend solely on the particular type of crankcase on which the cylinder happens to be mounted are excluded. Thus, the data obtained by this method show the performance that can be *approached* with a multi-cylinder design by reducing the induction-system losses, and the friction losses in the crankshaft and the auxiliaries, to a minimum. This method of correcting for friction losses was used in preparing some of the illustrations, and gives results that are slightly less favorable to the cylinder than would be obtained by the method used in the paper. The average distribution of the so-called "friction" losses in the modern V-type water-cooled aircraft engine is as shown in Table 3.

TABLE 3—DISTRIBUTION OF FRICTION LOSSES

Distribution	Indicated Power, Per Cent	Friction Losses, Per Cent
Pumping Losses	5.85	45.0
Piston, Piston-Ring and Connecting-Rod Friction	6.24	48.0
Crankshaft and Auxiliaries, including Valve-Gear	0.91	7.0
Total Friction Losses	13.00	100.0

MULTI-CYLINDER PERFORMANCE

In estimating multi-cylinder performances from single-cylinder test-results, factors other than friction losses must be taken into account. The single intake-pipe of the single-cylinder installation, together with the fact that lower induction-system depressions can be used due to the absence of the considerations of distribution, idling and acceleration, results in an indicated power-output for the cylinder on the universal-test engine considerably greater than that of the same cylinder on a multi-cylinder engine. With large cylinders, the lower induction-system losses often more than offset the high friction-losses of the single-cylinder crankcase, and result in brake power-outputs from the single-cylinder installations that exceed the brake power-outputs of the same cylinders on multi-cylinder engines.

Fig. 18 illustrates the difference between single and multi-cylinder performance for a 5 x 7-in. cylinder. It will be noted that the single cylinder gives a higher brake power-output, a much higher indicated-output and a higher "peak" on the power curve, than the same cylinder on a multi-cylinder engine. In the case of a smaller cylinder, such as the type-K shown in Fig. 1, it is probable that the uncorrected brake power-output obtained on the universal-test engine would be exceeded in a well-designed multi-cylinder installation. However, so many variable factors are involved, such as the number and the arrangement of the cylinders and the different valve-timing and manifolding required on the multi-cylinder engine, that no accurate method of predicting multi-cylinder performance from a single-cylinder test has yet been evolved. With certainty, it can be said only that the results obtained with the methods of correction used in Appendix 1 or in the paper have been approached, but not yet equaled, in the best multi-cylinder designs.

OTHER INVESTIGATIONS

In addition to determinations of the effect of the mixture-ratio on the performance and of the magnitude of the friction losses, an investigation of the power-output at various rotational speeds is conducted usually on an experimental cylinder. Also, in the case of an air-cooled cylinder, an investigation is made of the performance with varying air-blast velocities and with varying air-blast direction. For a water-cooled cylinder, an investigation is made also of the performance with varying cooling-water temperatures and rates of flow, and one for endurance qualities for long periods of full-throttle operation.

Any or all of the above investigations can be conducted with different compression-ratios and valve-timing. All of the single-cylinder work is done at full throttle, since at throttled speeds the wide departure in the induction system from multi-cylinder conditions makes the results of little value.

Fig. 19 shows comparative performance curves of a typical water-cooled and an air-cooled cylinder, at con-

stant speed and with varying mixture-ratios. The importance of this particular type of curve cannot be overestimated in single-cylinder work since, with a given compression-ratio and speed, it indicates clearly the points of maximum efficiency and maximum power-output of a given cylinder. It will be noted that the compression-ratio of the two cylinders is approximately the same and that, therefore, the results can be compared safely. The water-cooled cylinder evidently is capable of satisfactory operation on leaner mixtures and with lower specific fuel-consumption than the air-cooled cylinder. However, as the mixture becomes richer, the air-cooled cylinder compares

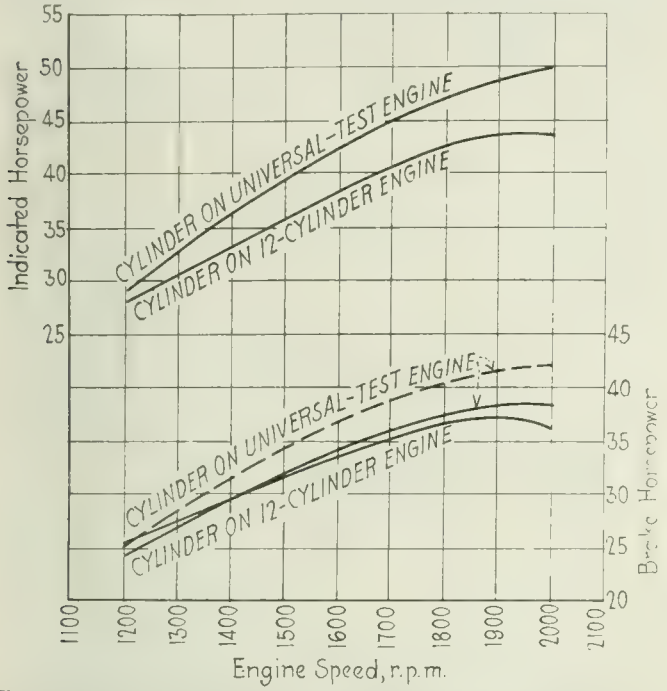


FIG. 18.—CURVES SHOWING THE DIFFERENCE IN THE PERFORMANCE OF A SINGLE-CYLINDER AND A MULTI-CYLINDER ENGINE USING THE SAME CYLINDER DESIGN

more favorably with the water-cooled type. It is interesting to note that, with the leanest mixture at which the air-cooled cylinder will run, the difference between the temperatures of the two cylinders, measured at the hottest point, was only 200 deg. fahr. and, with the mixture-ratio decreased to 11.3, this difference was reduced to approximately 130 deg. fahr. In several instances it has been found possible to reduce the fuel consumption of a similar air-cooled cylinder to as low as 0.453 lb. per b. hp-hr., but this could be done only under favorable conditions and with a considerable reduction of power-output. The curves of Fig. 19 are, therefore, considered typical. The difference in the mean effective pressure developed by the two cylinders is due to differences in their design, and is not attributable to the different method of cooling. A higher mean effective pressure for the water-cooled cylinder would result in only slightly higher temperatures.

Fig. 20 is an interesting comparison between two air-cooled cylinders of identical size and method of construction; one has a hemispherical head with two valves, and the other a flat head with one intake and two exhaust-valves. These are respectively the type-J and type-I cylinders illustrated in Mr. Herron's previous paper.[12] It will be noted that the hemispherical-head cylinder shows a lower fuel-consumption, a higher power-output and a lower

[12] See THE JOURNAL, April, 1922, p. 231.

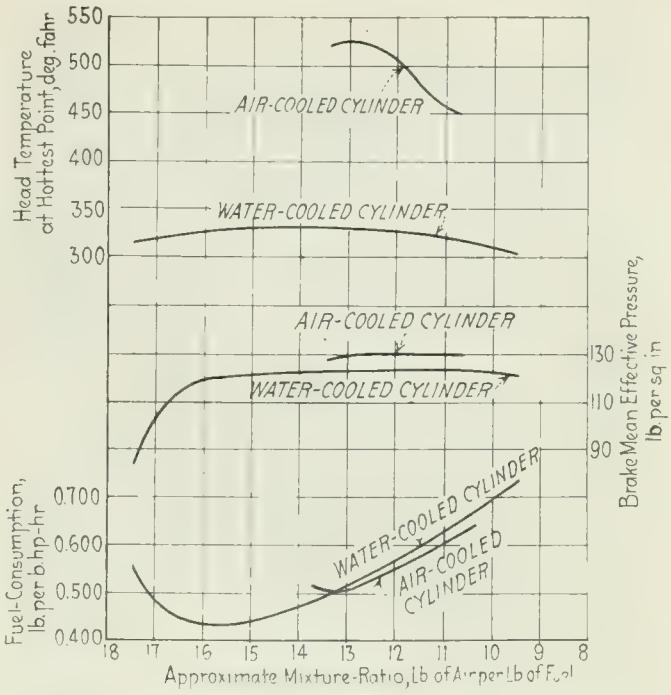

Head Temperature at Hottest Point, deg. fahr.
AIR-COOLED CYLINDER
WATER-COOLED CYLINDER
AIR-COOLED CYLINDER
WATER-COOLED CYLINDER
Brake Mean Effective Pressure, lb. per sq. in.
Fuel-Consumption, lb. per b.hp-hr.
WATER-COOLED CYLINDER
AIR-COOLED CYLINDER
Approximate Mixture-Ratio, lb. of Air per Lb. of Fuel

FIG. 19.—COMPARATIVE PERFORMANCE CURVES OF A 5 × 7-IN. WATER-COOLED CYLINDER AND A 5½ × 6½-IN. AIR-COOLED CYLINDER

Type of Cylinder	Air-Cooled	Water-Cooled
Compression-Ratio	5.3	5.4
Water-Outlet Temperature, deg. fahr.		170
Air Temperature, deg. fahr.	32	90
Air-Blast Speed, m.p.h.	100	
Speed of Engine, r.p.m.	1,650	1,700

head-temperature than the flat-head cylinder tested under the same conditions. This bears out very strikingly the statements made in the paper in regard to the shape of

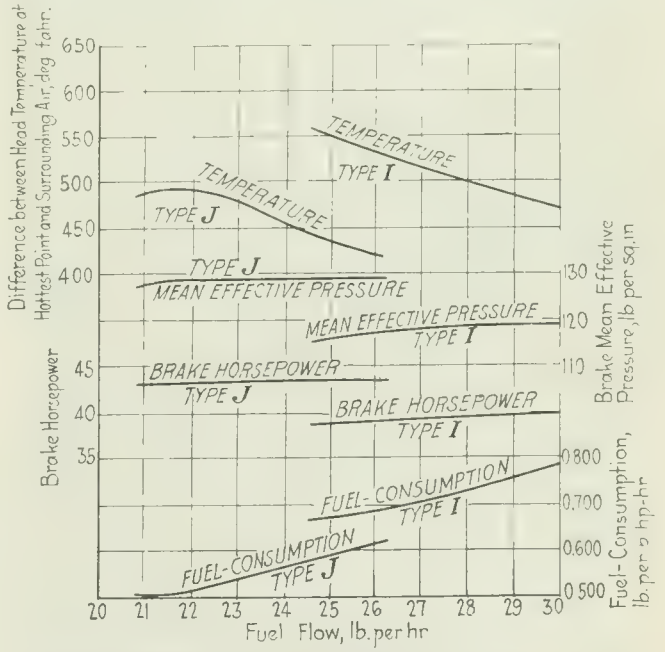

Difference between Head Temperature at Hottest Point and Surrounding Air, deg. fahr.
TEMPERATURE TYPE I
TEMPERATURE TYPE J
TYPE J MEAN EFFECTIVE PRESSURE
MEAN EFFECTIVE PRESSURE TYPE I
Brake Mean Effective Pressure, lb. per sq. in.
Brake Horsepower
BRAKE HORSEPOWER TYPE J
BRAKE HORSEPOWER TYPE I
FUEL-CONSUMPTION TYPE I
FUEL-CONSUMPTION TYPE J
Fuel-Consumption, lb. per b.hp-hr.
Fuel Flow, lb. per hr.

FIG. 20.—COMPARATIVE PERFORMANCE CURVES OF A FLAT-HEAD THREE-VALVE AIR-COOLED CYLINDER AND A HEMISPHERICAL-HEAD TWO-VALVE AIR-COOLED CYLINDER

Type of Cylinders	I	K
Form of Cylinder-Head	Flat	Hemispherical
Compression-Ratio	5.30	5.37
Diameter of Intake-Valve, in.	2⅛	2⅛
Lift of Intake-Valve, in.	9/16	9/16
Number of Exhaust-Valves	2	1
Diameter of Exhaust-Valves, in.	1½	2¼
Lift of Exhaust-Valves, in.	13/32	9/16
Speed of Engine, r.p.m.	1,650	1,650
Blast Speed, m.p.h.	100	100
Air Temperature, deg. fahr.	74	32

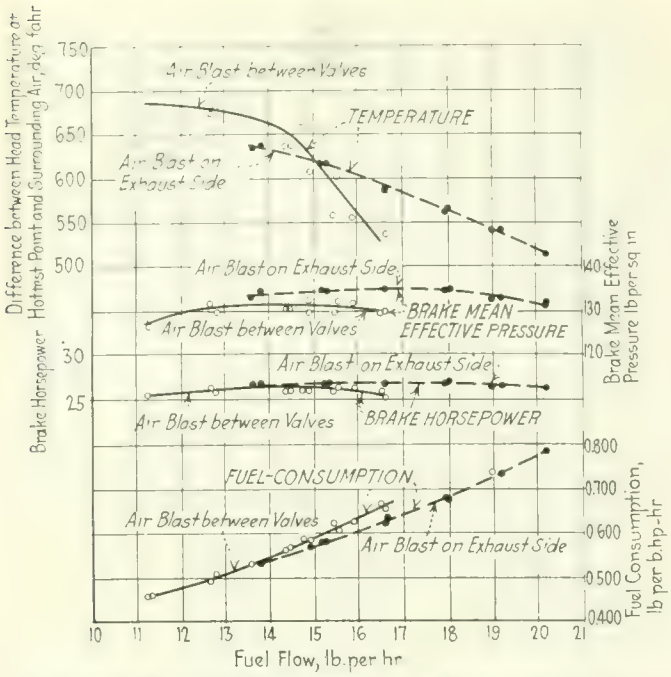

Difference between Head Temperature at Hottest Point and Surrounding Air, deg. fahr
Brake Horsepower
Brake Mean Effective Pressure, lb per sq in
Fuel Consumption, lb per b hp-hr
Fuel Flow, lb per hr
Air Blast between Valves
TEMPERATURE
Air Blast on Exhaust Side
BRAKE MEAN EFFECTIVE PRESSURE
BRAKE HORSEPOWER
FUEL-CONSUMPTION

FIG. 21—CURVES SHOWING THE VARIATION WITH FUEL FLOW AND WITH TWO DIFFERENT BLAST DIRECTIONS IN THE PERFORMANCE OF A TYPE-K CYLINDER

the combustion-chamber. These results are uncorrected for the friction losses, since both cylinders were tested on the same universal-test engine and dynamometer. The left-hand end of each curve in Fig. 20 represents the point beyond which the fuel-flow could not be reduced without causing a severe preignition and immediate power-drop. The most interesting material for cylinder construction for automotive vehicles is cast iron, due to its low cost,

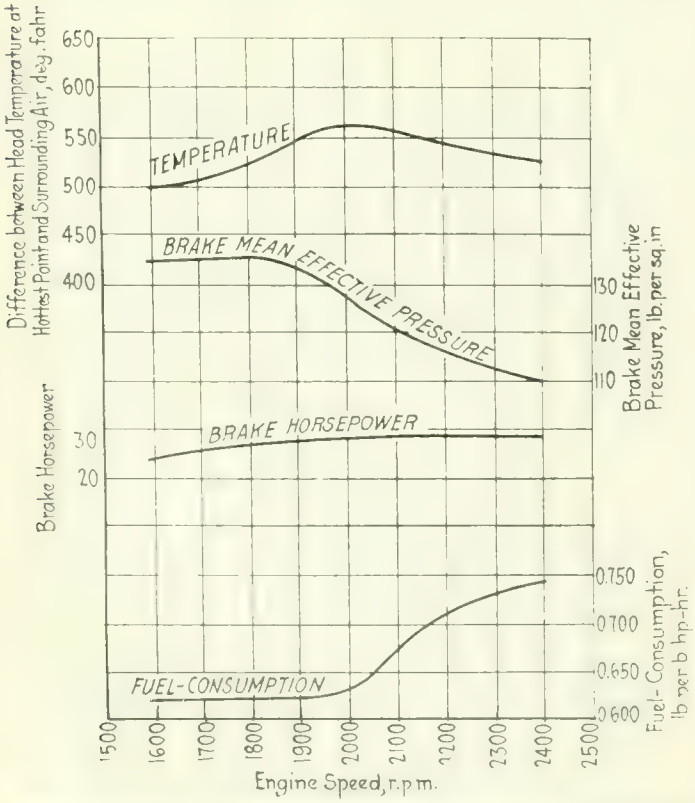

Difference between Head Temperature at Hottest Point and Surrounding Air, deg. fahr
Brake Horsepower
Brake Mean Effective Pressure, lb per sq in
Fuel-Consumption, lb per b hp-hr
Engine Speed, r p m
TEMPERATURE
BRAKE MEAN EFFECTIVE PRESSURE
BRAKE HORSEPOWER
FUEL-CONSUMPTION

FIG. 22—VARIATION IN THE PERFORMANCE OF THE TYPE-K CYLINDER WITH THE SPEED

ease of casting and the absence of the inserted valve-seats and spark-plug bosses required with aluminum.

Figs. 21, 22 and 23 should be of especial interest to the automobile engineer, since they represent actual test-results on a cylinder with cast-iron head of the type illustrated in Fig. 1 of the paper. While this cylinder has a steel barrel, it could be made easily with an integral cast-iron barrel having cast-iron fins without affecting the performance materially. Tests made by the Engineering Division indicate that the material of the barrel below the top of the piston-travel does not have any great effect on the cylinder performance, provided it is reasonably well finned and there is no serious obstruction to the heat-flow from the head to the barrel.

Fig. 21 illustrates the performance of the type-K cast-iron-head cylinder having a compression-ratio of 5.32 to 1, with varying rates of fuel-flow and with two differ-

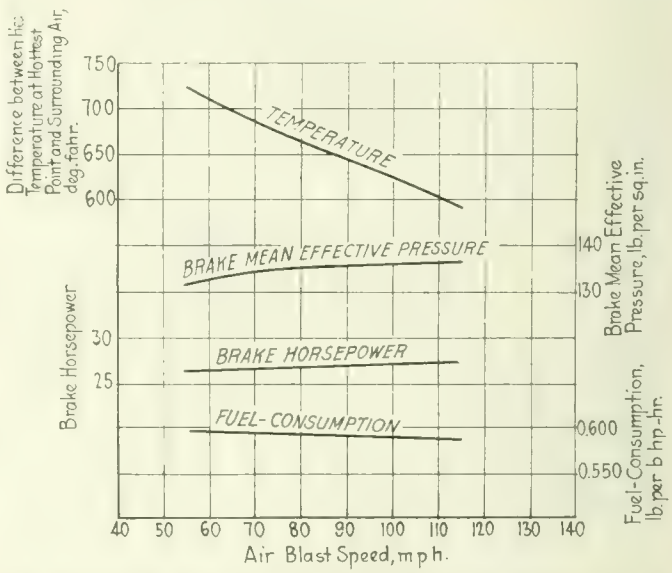

Difference between Head Temperature at Hottest Point and Surrounding Air, deg. fahr.
Brake Horsepower
Brake Mean Effective Pressure, lb per sq in.
Fuel-Consumption, lb per b hp-hr.
Air Blast Speed, m p h.
TEMPERATURE
BRAKE MEAN EFFECTIVE PRESSURE
BRAKE HORSEPOWER
FUEL-CONSUMPTION

FIG. 23—CURVES SHOWING THE VARIATION IN THE PERFORMANCE OF THE TYPE-K CYLINDER WITH THE BLAST SPEED

ent blast-directions. One set of curves was obtained with the air-blast directed against the exhaust side of the cylinder, which had a port-arrangement similar to that shown in Fig. 4 of the paper. The other set of points was obtained with the air-blast directed between the ports, at right angles to a plane through the two valves It will be noted that the flow of fuel could be reduced to a lower value with the blast directed between the valves, which is not in agreement with results obtained by the Royal Aircraft Establishment on the effect of blast direction. This discrepancy may have been caused y variations in the spark-plugs used during the tests of the type-K cylinder. In both cases the limit below which the flow of fuel could not be reduced was the point at which severe preignition occurred. This preignition probably was caused by the spark-plugs becoming so hot as to ignite the charge prematurely, and slight differences in the spark-plugs used in the two tests might account for the earlier occurrence of preignition with the exhaust-side air-blast. The power-output and the fuel economy obtained are considered very creditable for a cylinder of this size using cast iron as the head material. An interesting fact in connection with these performance results is that the cylinder operates in a reliable manner with temperatures at the hottest point on the head that have heretofore been considered prohibitive. It appears, however, that such temperatures are permissible provided the temperatures of the spark-plugs and

the exhaust-valves are not excessive. In the case of this cylinder, the exhaust-valve ran at a lower temperature than is experienced usually with most water-cooled designs with normal water-temperatures. The spark-plugs were the best that could be obtained from the standpoint of resistance to preignition. This same cylinder has run without failures for nearly 50 hr. at wide-open throttle with head-temperatures of over 500 deg. fahr.

Fig. 22 shows the variation in performance with speed of the same cylinder with the air-blast directed against the exhaust side. The valve-timing of this particular cylinder was designed for a normal speed of 1800 r.p.m., which accounts for the considerable decrease in mean effective pressure at the higher speeds. As shown in Fig. 21, the fuel-consumption of 0.64 lb. per b. hp-hr. at the normal speed of 1800 r.p.m. could have been reduced considerably by the use of a leaner carbureter-setting. The change in the head-temperature with the speed of rotation is small, which is typical of air-cooled cylinders of this type. The high fuel-consumption and the high blast-speed shown by this set of curves were used as a safety precaution on account of operating the cylinder at speeds so greatly in excess of those for which it was designed.

Fig. 23 shows the effect of a reduction in the air-blast speed on the type-K cylinder, with the air-blast directed against the exhaust side. With the air-blast reduced to one-half its original value, the rise in the head-temperature was slightly over 100 deg. fahr., and the operation of the cylinder was still satisfactory with very little loss of power or increase in the specific fuel-consumption. However, on further reduction of the air-blast speed, preignition occurred.

EXHAUST-VALVE COOLING

The problem of exhaust-valve cooling has been discussed by Mr. Heron but, due to its primary importance in air-cooled cylinder work, it is of interest to mention some of the laboratory experiences in regard to this important problem. The exhaust-valves on many of the air-cooled cylinders developed by the Engineering Division run somewhat cooler than the exhaust-valves of a similar size in water-cooled cylinders, although the parts of the cylinder immediately surrounding the valves in every case run at a considerably higher temperature in the air-cooled cylinder. The cause of this apparently contradictory condition seems to lie in the fact that, in designing air-cooled cylinders, it has been realized that special attention to exhaust-valve cooling was necessary. The valves, guides and ports therefore were designed to afford the maximum opportunity for heat dissipation from the valve, and the valve itself has in most cases been designed with large areas for heat dissipation from the stem and the seat. This has resulted in valves that run cooler than valves of equal size in water-cooled cylinders that have had only ordinary attention to the design factors necessary for proper exhaust-valve cooling. The valve and port design that appears to give the best exhaust-valve cooling is that illustrated in Fig. 12 of the paper and developed personally by Mr. Heron. Just which of the features of this design is responsible in greatest measure for the excellent cooling of the valve has not yet been determined. The Engineering Division is planning to conduct a series of tests in the near future that will establish the basic factors of valve and port design that promote effective cooling of the exhaust-valve. The indications are that there is no fundamental reason why the exhaust-valve in an air-cooled cylinder should run at a lower temperature than a similar valve in a water-cooled cylinder, and it is believed that the differences in design account fully for the differences in the cooling that have been observed. It appears fairly certain that, if a design similar to that shown in Fig. 12 were used in a water-cooled cylinder, the temperature of the valve would be even lower than in the case of an air-cooled cylinder, under similar conditions of power-output and mixture-strength.

With further reference to the problem of valve cooling, it should be remembered that excess fuel or oil in the combustion-chamber has a very marked effect on the temperature of the exhaust-valve. It is very easy for the experimental engineer to lose sight of this fact and attribute an improvement in valve cooling to changes in the design, when the lower temperature is merely due to a richer mixture or a larger amount of lubricating oil passing the piston. In comparing exhaust-valve temperatures, it is absolutely necessary to hold the mixture-ratio and the amount of oil reaching the combustion-chamber as nearly constant as possible, since these two factors may have a more powerful effect than any changes in the design of the valve or the port. A very badly designed exhaust-valve can be made to run at comparatively low temperatures by using an excessively rich mixture or an excessive amount of lubricating oil.

INTERNALLY COOLED VALVES

The Engineering Division has done a considerable amount of experimenting with internally cooled valves; that is, valves with hollow stems filled with certain high-boiling-point liquids. The object of such arrangements is to afford a rapid conduction of heat from the head of the valve to the upper portions of the valve-stem, thus causing a higher rate of heat-transfer due to the greater temperature-difference between the stem and the valve-guide. This method of valve cooling is fairly effective and often adds very little to the cost of the valve since, in many cases, a hollow-stem valve must be used, whether or not it is filled with liquid, to provide the necessary stem-surface for the proper heat-conduction without excessive weight. It is probable that internal valve-cooling will be found unnecessary for anything but very large air-cooled cylinders required to run for long periods at full throttle, since careful attention to the design will make internal cooling unnecessary in water-cooled cylinders and in air-cooled cylinders in which the valve conditions are less severe.

AIR AND WATER-COOLED TYPE COMPARISONS

In concluding Appendix 1, it is of some interest to review the relative advantages and disadvantages of the air-cooled and water-cooled types of engine from the point of view of the not inconsiderable experience of the Engineering Division with both types. It seems almost certain that the water-cooled engine will be shorter and more compact, due to the smaller space required between the adjacent cylinders, and particularly if it is conceded that the radiator may occupy space not required for other purposes with either type of engine. It appears evident also that the water-cooled engine will have the advantage of convenience due to the removable head, since air-cooled design has not yet reached the stage where the removable cylinder-head is entirely practicable. The water-cooled engine probably will have a slight advantage in regard to silence of operation also, provided equal care in the design is used for both types. This is on account of the fact that the block-cylinder construction lends itself more readily to the enclosed valve-gear, and the water-jackets seem to form a fairly effective barrier against excessive

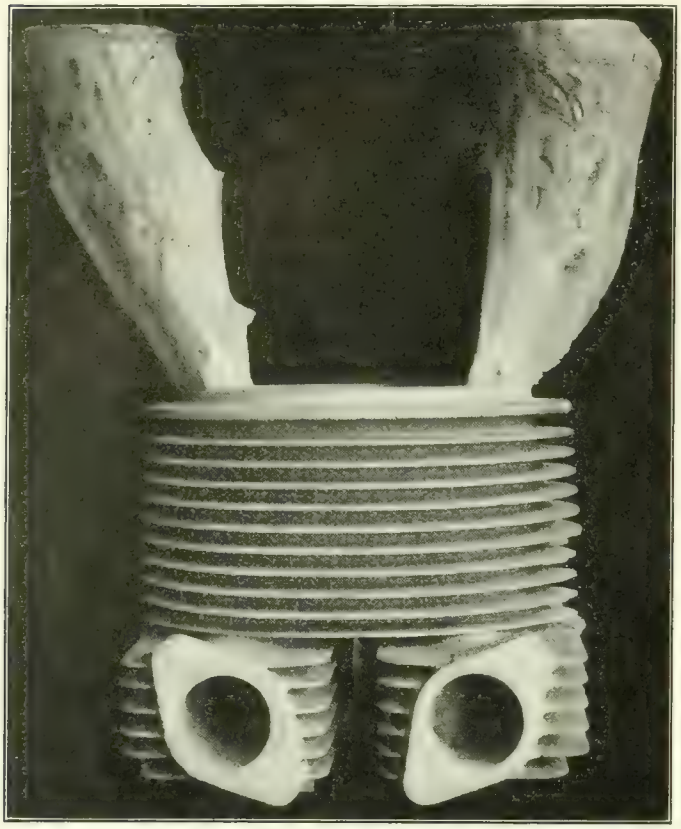


FIG. 24—THE TYPE-H CYLINDER-HEAD PRODUCED BY DOUBLE POURING

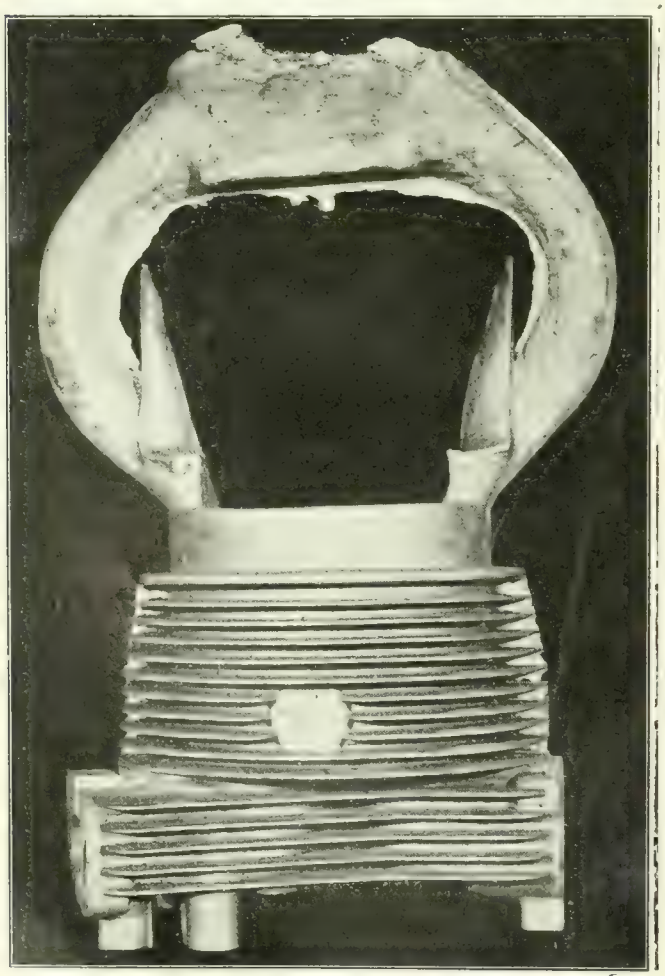


FIG. 25—THE TYPE-I CYLINDER-HEAD PRODUCED BY SINGLE POURING

noise. Perhaps the greatest advantage of the water-cooled engine lies in the fact that, for a given grade of fuel, a higher compression-ratio and a leaner mixture can be used, which naturally results in a somewhat more economical engine. While the advantage of the water-cooled engine in this respect is greatest at full throttle and becomes less important for engines required to operate largely at throttled speeds, it warrants consideration where fuel economy is a highly important factor. This fact conflicts with the general opinion of the motoring public that the air-cooled automobile is inherently more economical than the water-cooled vehicle, which opinion has undoubtedly resulted from the fact that the best known American air-cooled car has been designed with factors outside of the engine that result in a high economy when measured in miles per gallon.

The air-cooled engine, on the other hand, scores heavily from the point of view of convenience of handling, especially under extreme weather conditions, either of heat or of cold. The wide temperature-range under which an air-cooled engine will give satisfactory operation adapts it for service under very severe conditions and the freedom from freezing and boiling is an item that every motorist can appreciate. In the well designed air-cooled vehicle, the cooling system should require no attention whatever for months at a time. Other cooling-system troubles, characteristic of the water-cooled engine and absent in the air-cooled engine, are those due to formation of scale in the water-jackets and the ever-present leakage from radiators, hose connections and water-pumps. The formation of scale is a factor of more importance than is commonly supposed and if heavy, may result in definitely poor operation of a water-cooled engine at maximum power-output. Table 4 illustrates the effect of a small amount of scale on the wall temperatures of a water-cooled cylinder.

TABLE 4—EFFECT OF SCALE FORMATION ON CYLINDER-WALL TEMPERATURES[14]

Temperature, Deg. Fahr.	No Scale	Scale	Thickness of Scale, In.
Water Outlet	171	171	....
Cylinder Barrel	182	181	....
Combustion-Chamber Wall	253	292	0.012
Exhaust-Valve Seat	241	316	0.023
Head between Valves	307	391	0.025

[14]Water-cooled 5 x 7-in. cylinder run at full throttle at 1700 r.p.m. with constant cooling-water temperature. Compression ratio, 5.5 to 1. Fuel used, 20 per cent of benzol and 80 per cent of aviation gasoline.

The air-cooled powerplant also should be somewhat lighter in weight than the water-cooled powerplant since, in spite of the added length of the engine and the addition of cooling fins, fan and air-ducts, the elimination of water-jackets, radiator, pump, piping and water constitutes a saving in weight that will result in an overall saving for the air-cooled powerplant in most cases. The individual removable cylinders of the air-cooled engine are a convenience in overhauling that largely offsets the convenience of the removable head of the water-cooled engine.

CHOICE OF POWERPLANT TYPE

Without going into the question in detail, it appears that the well designed air-cooled and water-cooled powerplants are approximately equal in cost, ease of production, smoothness and flexibility of operation, and road performance, with cars of equal weight and engines of equal displacement.

In view of the above considerations, it is apparent that

the choice of the type of powerplant will depend on the individual conditions under which the vehicle is to be operated. It is the opinion of the writer, however, that

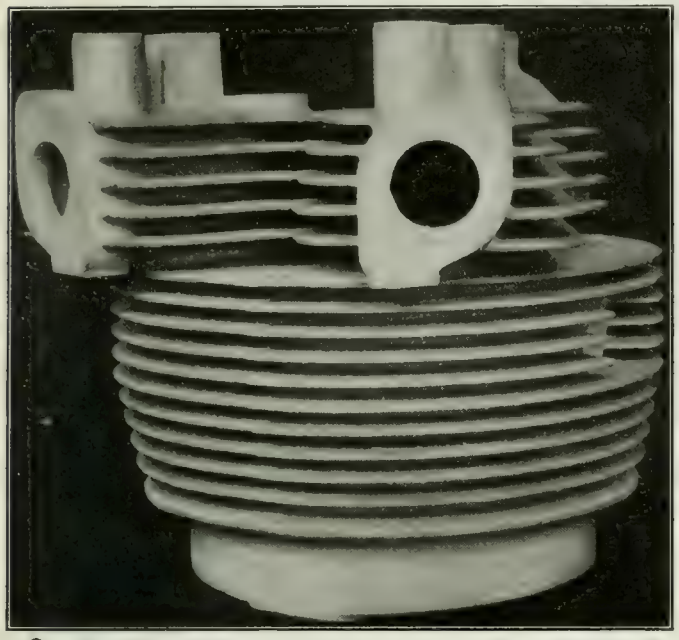


FIG. 26—VIEW OF THE TYPE-I CYLINDER-HEAD SHOWING THE PORTS

the advantages of the air-cooled engine from the standpoints of convenience to the driver and entire freedom from cooling-system trouble will result in a rapid and

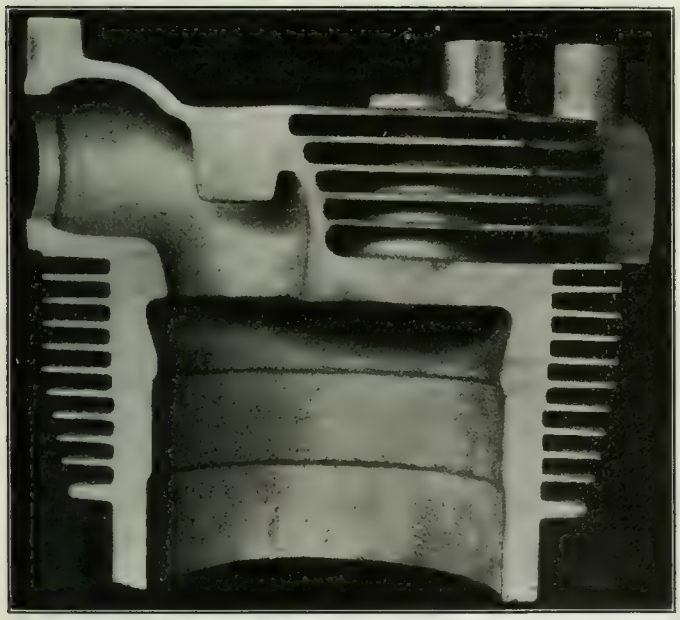


FIG. 27—SECTION OF THE TYPE-I CYLINDER-HEAD

healthy growth of this type of powerplant for automotive vehicles in this Country.

APPENDIX 2

FOUNDRY PRODUCTION OF AIR-COOLED CYLINDERS[15]

The production of air-cooled cylinder castings having fins cast integrally presents problems that are so different from those encountered in making water-cooled cylin-

[15] Contributed by E. H. Dix, Jr., in charge of the foundry and metallurgical branch, engineering division, Air Service, McCook Field, Dayton, Ohio.

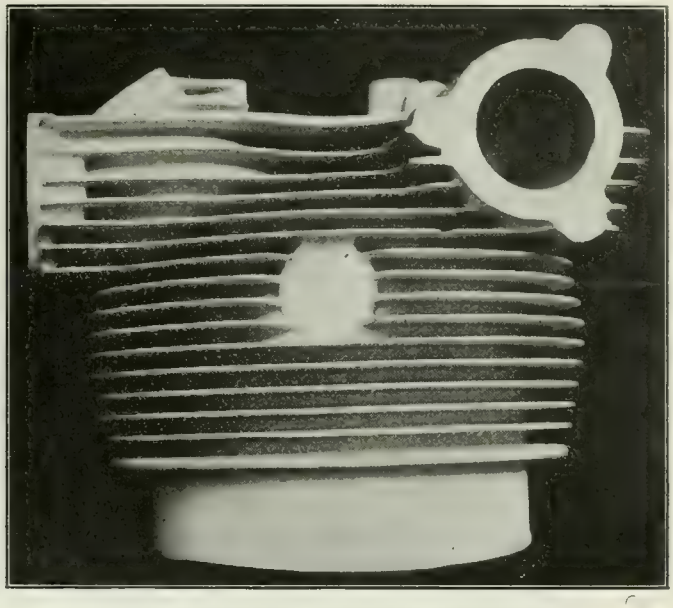


FIG. 28—THE TYPE-J TWO-PORT CYLINDER-HEAD

ders that there is much skepticism as to their ultimate practicability. The average engine-designer has had lit-

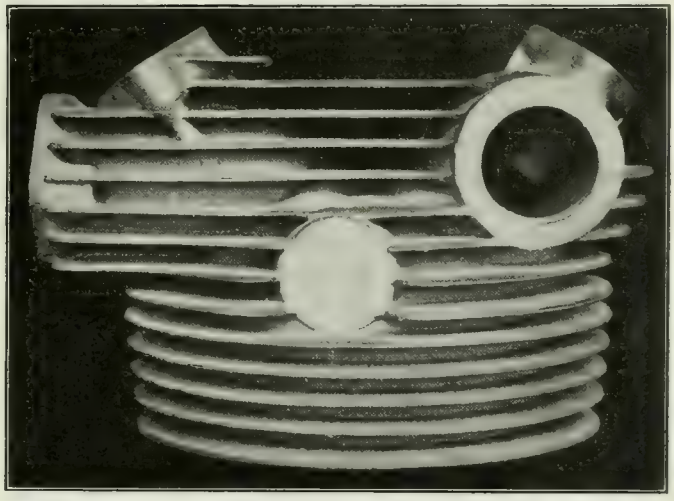


FIG. 29—THE TWO-PORT TYPE-K CYLINDER-HEAD

tle, if any, practical experience in the foundry. He is, therefore, more or less dependent upon the judgment and

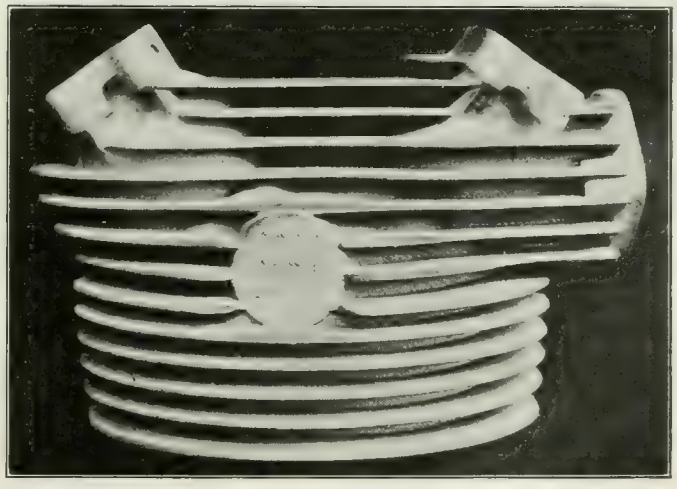


FIG. 30—ANOTHER VIEW OF THE TYPE-K TWO-PORT CYLINDER-HEAD

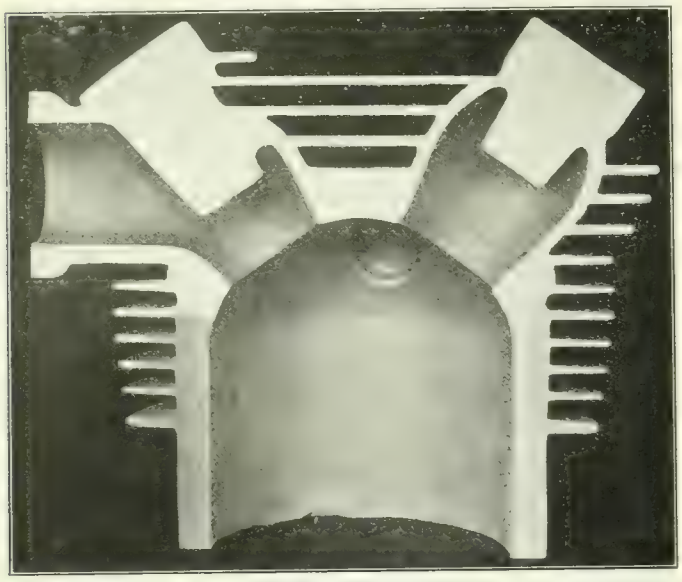


FIG. 31—SECTION OF THE TYPE-K CYLINDER-HEAD

advice of the foundryman. Foundrymen, as a class, are slow to adopt new ideas, and their judgments are apt to be based on past experience rather than future possibilities. This characteristic is evident from a study of the progress, or rather lack of progress, that has been made in foundry methods until recent years. The foundry has been the last manufacturing department to attract the attention of the technical man. Men learned the foundry trade by growing up in a foundry, a hard and tedious method; but, once acquired, knowledge was possessed which was carefully guarded, especially from men in the other branches of the industry. This policy or habit retarded advancement and there was little exchange of ideas. It is not surprising, then, that the foundryman would advise against attempting to make castings with such long thin fins as closely spaced as is required by efficient design. Also, after having once given such advice, it is natural that, where such designs were attempted, they failed due to foundry difficulties. It merely proved that the foundryman's judgment had been correct; but, as an actual fact, his cooperation had been only half-hearted; he had not expended his best efforts. However, if it is once proved to him what can be

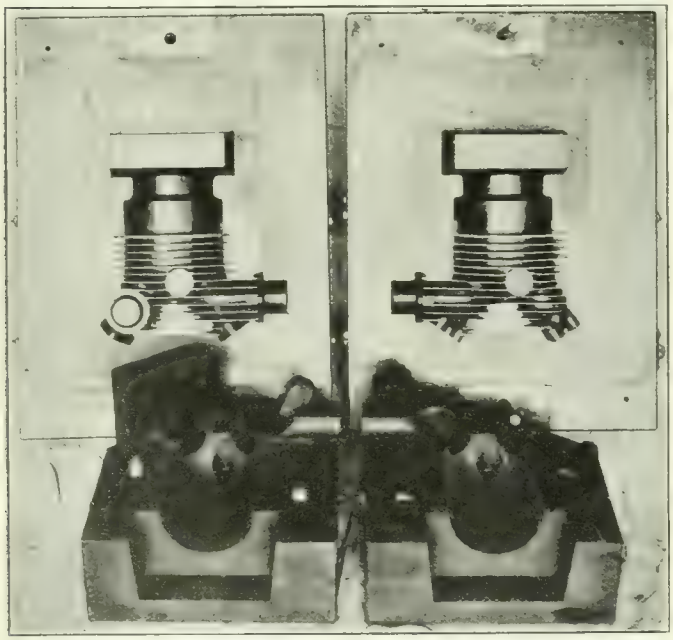


FIG. 32 THE PATTERN EQUIPMENT USED TO PRODUCE THE TYPE-K CYLINDER-HEAD

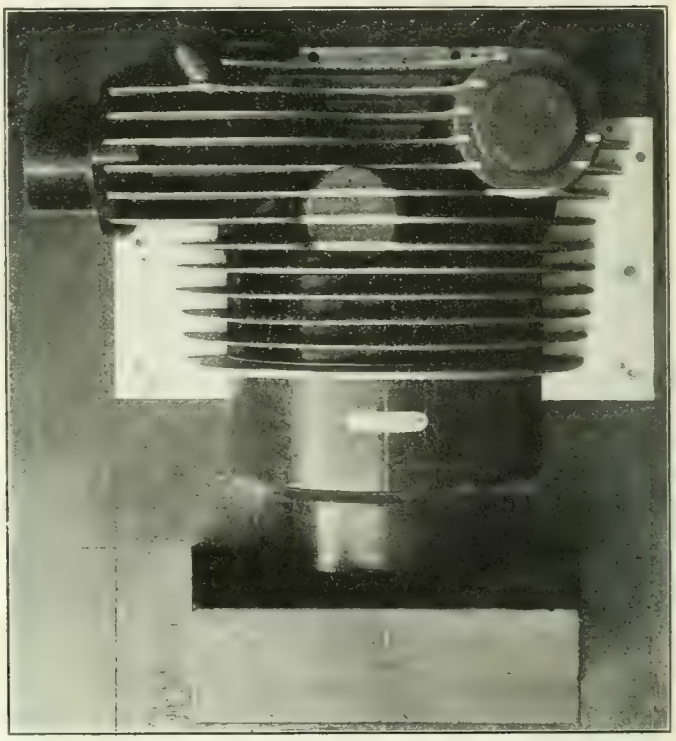


FIG. 33 A DETAILED VIEW OF THE PATTERN PLATE FOR THE DRAG PORTION OF THE TYPE-K MOLD

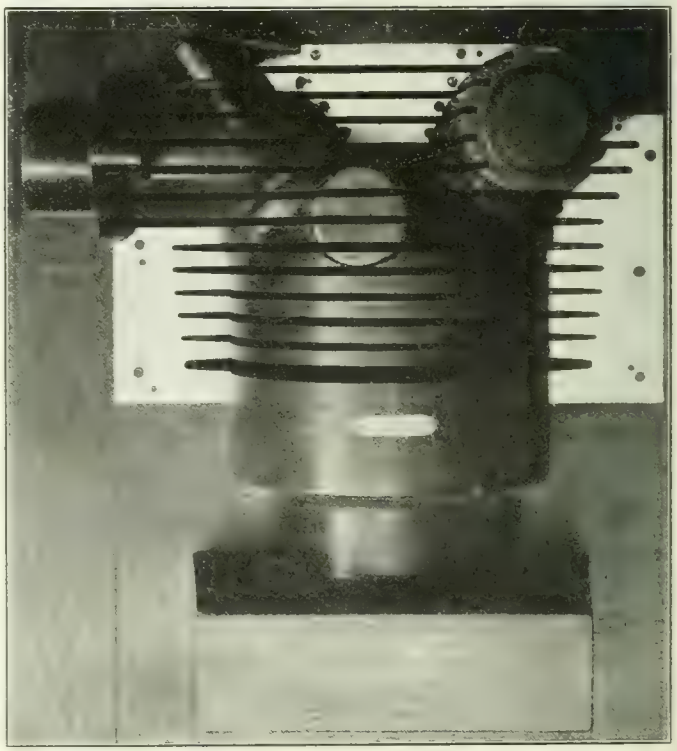


FIG. 34—THE PATTERN PLATE FOR THE TYPE-K CYLINDER-HEAD WITH THE SHEET-ALUMINUM FINS REMOVED

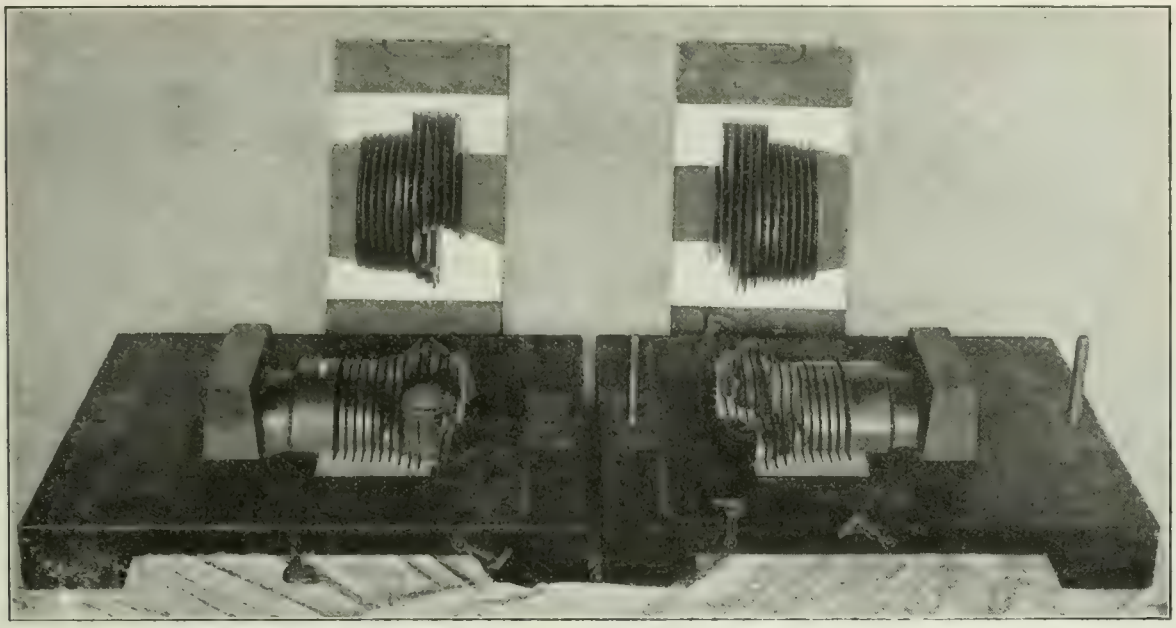


FIG. 35.—VIEW OF THE TYPE-K PATTERN EQUIPMENT SHOWING HOW THE SHEET-ALUMINUM FINS ARE MOUNTED

done, he will not be content until he has accomplished corresponding results.

CASTING ALUMINUM-ALLOY CYLINDER-HEADS

It is hoped that a discussion of the experience of the Engineering Division foundry in casting aluminum-alloy cylinder-heads for air-cooled engines will stimulate interest and encourage the development of air-cooled motor-car engines. The various types of cylinder-head casting made to date are illustrated in Figs. 24 to 31. Both the four-port type-H shown in Fig. 24 and the three-port type-I castings illustrated in Figs. 25 to 27 require outside cores, and this is a disadvantage where accurate smooth fin-surfaces are required. The two-port type-J casting shown in Fig. 28 is an improvement in that only a cover core for the intake port is required. This can be eliminated by having the lugs made as loose pieces to draw in toward the center.

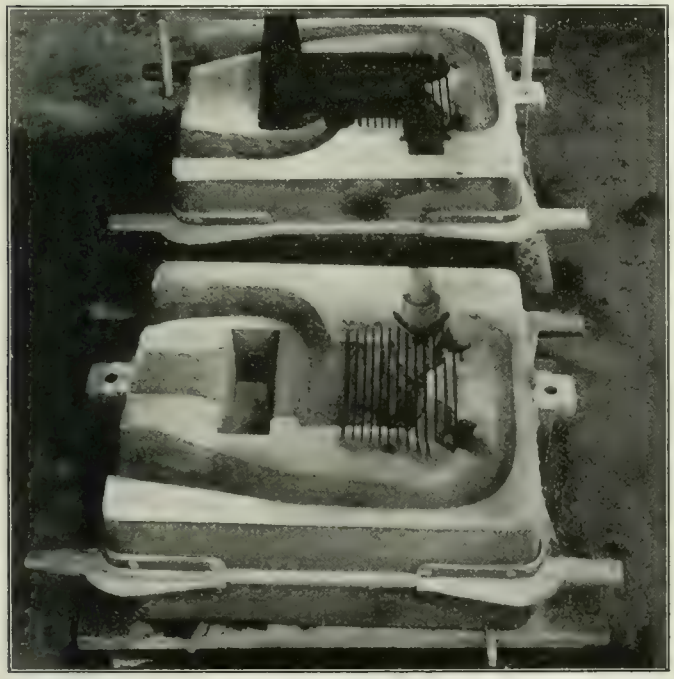


FIG. 36.—THE TYPE-K MOLD AND CORE SHOWING THE METHOD OF GATING

The two-port type-K castings illustrated in Figs. 29 to 31 require no outside cores, and the body core is made in one piece. This cylinder-head is a triumph of design from the foundry viewpoint, and shows what can be accomplished in the way of simplifying the foundry processes if due consideration is given that point in the original layout.

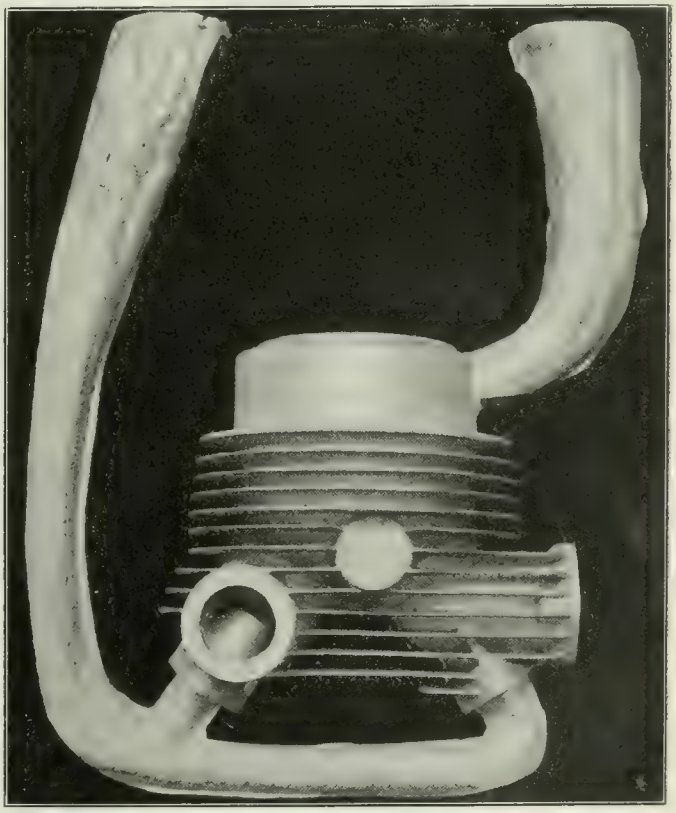


FIG. 37.—THE TYPE-K CYLINDER-HEAD CASTING WITH THE GATES AND THE RISER ATTACHED

The greatest difficulty in the production of these cylinder-heads is in the molding. Once a satisfactory mold is prepared, the metal difficulties are few; and, for this reason, much emphasis must be placed on the pattern equipment. Metal fins are a necessity; although, for experimental work, the remainder of the pattern can be made of wood. Drawing the pattern is a difficult operation at best; and, if wooden fins are used, the warpage is sufficient to cause breaks in the tongues of sand between the fins. The patterns for the first three cylinders described were made of wood, had sheet-aluminum fins and were mounted on wooden match-plates. These proved very satisfactory for the development stage.

The pattern equipment for the two-port type-K cylinder is shown in Fig. 32. The simplicity of the core-box deserves comment; the core is made in one piece and thus eliminates all chance for core-shifts and lack of uniformity due to pasting cores. Both plates are constructed so that the fins strip through the pattern, as is brought out by the detailed view of the pattern plate for the drag in Fig. 33. Fig. 34 shows the fins removed. The patterns and plates are of wood, although the plates are reinforced by sheet aluminum. The fins are sheet aluminum mounted as illustrated in Fig. 35. This equipment was made for hand operation and has proved to be very successful, except that, after considerable use, the fit of the fins in the pattern has become loose in some places, which allows thin points of sand to be rammed between the fin and the pattern. These must be washed off to prevent dirty castings. An all-metal pattern for production work would obviate this trouble. By stripping the fins through the pattern-board, the drawing of the pattern becomes a simple operation and most of the molding difficulties are overcome. This method is believed to be more satisfactory than the joint stripper-plate.

The type-K cylinder with the pattern arrangement illustrated in Fig. 35 is well adapted to machine-molding except for the substitution of metal in place of wood. Either a jolt stripper or a jolt and roll-over machine can be used. If used on a jolt and roll-over machine, the plate to which the fins are secured would be attached to the draw-arm and the other plate carrying the pattern would be hung from the first plate by close-fitting pins which would not engage until the fins had been withdrawn 1 in. or more, thus accomplishing two results in one operation.

In casting the aluminum cylinder-heads previously illustrated, dry-sand molds have been used exclusively. Sand from the ordinary heap, strengthened by molasses water, has been found to be satisfactory. Facings are unnecessary and lead to complications. Both halves of the mold are sprayed with molasses water, and the core is set in the drag. The two halves are then placed separately in a core-oven and baked at about 400 deg. fahr. for 6 hr. The mold is then closed and poured while hot, as this aids in running the fins. Recently, attempts have been made to cast the type-K cylinder-head in green sand. These experiments seem to indicate that the green-sand mold is not suitable for this type of work. To run the fins in green sand, it is necessary to pour at a higher temperature and much faster than in the case of dry sand. The fast pouring often causes the narrow tongues of sand to wash, and seems to cause cold-shuts where the fins join the body. The metal has a tendency to blow when poured rapidly into the green-sand molds. As a result of these experiments, dry-sand molds are strongly recommended. The splendid success attained with this type of mold gives little excuse for making these heads in cores that give inaccurate, rough castings.

GATING FOR ALUMINUM-ALLOY CASTING

The experience with methods of gating for aluminum alloys is also of interest. Fig. 24 shows how some of the first cylinder-heads were poured. These were poured two-up, and the arrangement was such as to get the metal into the mold as quickly as possible. Although it might be argued that this method is likely to cause the mold to wash and also to cause drossy metal, no difficulty was experienced in this connection. Fig. 25 illustrates a similar scheme, except that single instead of double pouring was used. A dirt-trap ring above the cylinder was added as an extra precaution. A pouring temperature of 1425 deg. fahr. was used with the methods of gating already described.

With the type-K cylinder, bottom-pouring was tried and found to be very successful. Fig. 36 shows the open mold and illustrates this method of gating. The casting with the gates and the riser attached is illustrated in Fig. 37. This casting was poured at 1460 deg. fahr.

It had been customary to take off three rows of vents from each fin in both the cope and the drag, to allow easy escape of the gas and to prevent short-run fins. However, no vents were taken off the fins of the casting shown in Fig. 37, and the fins were full-run and much smoother than when vents were taken off. The elimination of the vents will save much time in the molding, and is particularly desirable for machine-molding where the operator is not a skilled molder. Another thing that is being considered is the number of wires required to support the sand between the fins. For the hand-rammed dry-sand molds, three rows of wires have been used in both the cope and the drag. However, with machine-molding, it is believed that this can be reduced to one row or perhaps eliminated altogether, except in one or two very deep draws. This will be a very considerable item in production.

The mold shown in Fig. 36 was completely prepared by hand in about 2 hr. by the use of the stripper-plate pattern illustrated in Fig. 35, although it was necessary to wash the edges between each fin, due to the fine fins of sand caused by looseness in the fit of the fins in the pattern. By the elimination of this loss of time and by having the gates and the risers included on the boards, the time of molding could easily be cut in half. With machine-molding, a production of 8 to 10 per hr. might be obtained easily.

It is hoped that this brief outline of the experience of the Engineering Division foundry will show that air-cooled cylinder-head castings of the types illustrated are far from being bad production propositions. They are, in fact, much less difficult than some of the water-cooled designs requiring complicated and intricate jacket-cores.

Cooling Capacity of Automobile Radiators

By E. H. Lockwood[1]

Annual Meeting Paper *Illustrated with* Charts

THE heat-dissipating properties of three types of radiator core have been investigated at the Mason Laboratory, Yale University. These include the fin-and-tube, the ribbon and the air-tube groups, so classified according to the flow of the water and the air. The ratio of the cooling surface to the volume is shown to be nearly the same in the fin-and-tube and the air-tube cores, while that of the ribbon core is somewhat greater. A formula is derived for computing the heat-transfer coefficient, which is defined as the number of heat units per hour that will pass from one square foot of surface per degree of temperature-difference between the air, and the water and is the key to radiator performance, as by it almost any desired information can be obtained. When the heat-transfer coefficients have been found for a sufficiently wide range of water and air-flows the cooling capacity of a radiator can be computed for any desired condition. In an appendix five fundamental and six derived formulas are given. These cover such topics as pump circulation, thermo-syphon circulation, limiting depth of core required, final temperatures, weight of water-flow and the like. The results of applying the formulas to six cores that were selected as representative of the three main types are illustrated by a series of charts.

A RADIATOR is used to cool the jacket-water of engine cylinders. Its ability to dissipate heat depends not only on the extent and form of its cooling surface, but also on the velocity at which the air and the water flow past the surface. The air velocity in the case of automobiles and trucks is frequently low, and must be supplemented by a fan driven by the engine.

The value of a radiator is determined by other factors than its ability to dissipate heat, but this alone will be considered in the present discussion which will describe a method of computing the cooling capacity of radiators, under any reasonable operating conditions, that is based on coefficients determined by laboratory tests. An application of the method has been made to several types of radiator and their cooling characteristics have been disclosed.

Classification of Radiators

A radiator contains tanks located on the top and at the bottom to receive and to distribute the water. A cellular portion, usually called the core, occupies the space between the top and the bottom tanks and serves to cool the water. Numerous small passages allow the water to flow through the core, while provision is made for air to circulate freely around the hot metal to remove the heat. In addition to the parts mentioned, a protecting case usually is added to support the radiator and to give a pleasing appearance to the front of the vehicle.

The core is made preferably of rectangular outline and of uniform depth or thickness. It is constructed in a variety of forms, but all have the same characteristic thin-walled water-passages, with free air circulating on their exterior. With regards to their heat-dissipating properties, cores may be divided into three classes: (*a*) fin-and-tube, (*b*) ribbon and (*c*) air-tube.

In the first type the water passages are straight tubes leading from the top to the bottom tanks, with fins attached to give an increased surface for removing the heat. The tubes usually are cylindrical, but occasionally are drawn in oval or flat forms. Disc fins are made by soldering to the tube at close intervals round or square metal plates of about twice the diameter of the tube. This method of construction is varied by using, instead of fins, strips that are punched to receive a row of tubes. A more common arrangement is called the continuous fin, since it consists of a larger plate punched to receive all the tubes of the core. Whatever the type may be, the fins are spaced about equal distances apart and are usually five or six per inch. The tubes are of ¼ to ⅜-in. diameter.

In the ribbon-core type the water passages are formed between parallel plates, which are separated slightly by crimping the edges, or by using a spacing wire and then soldering them. The water ribbons are made the full depth of the core, and extend from the top to the bottom, where they are fastened to the water-tanks. The ribbons have either straight or zigzag channels. They are separated at regular intervals by the attached ribs, or fins, which serve the double purpose of stiffening the core and increasing the amount of surface for dissipating the heat. The attached fins are laid out in regular lines and give to the front a cellular appearance of squares, diamonds or hexagons, according to the shape of the ribbons. Two sides of each air-passage as a rule are bounded by water ribbons and the others by fin surfaces. It is possible, however, to join the corners of zigzag ribbons together to form a core without connecting the fins, and this construction is sometimes used. The water passages in the ribbons are from 0.05 to 0.06 in. wide. The air cells are from 3/16 to ⅜ in. square.

Air-tube cores are made up of short tubes packed closely together in horizontal rows, with their ends flared and soldered to form the front and the back of the core. Air passes through the tubes, while the water fills the entire space around the tubes, and flows in any path from the top to the bottom. In appearance air-tube cores resemble ribbon cores; and both belong to the cellular class. Air tubes have no fins, the surface being heated by direct contact with the hot water. In some cases baffles, or dents, are formed in the tubes to increase their effectiveness in cooling. This result is produced, not by an increase of the surface, but by a turbulence in the air-flow that renders the same amount of surface more effective. Air-tube cores have been made with both round and square tubes, but neither type has been much used owing perhaps to the cost of manufacture. Diagrammatic drawings of all three types of core are shown in

[1] M.S.A.E.—Assistant professor of mechanical engineering, Yale University, New Haven, Conn.

Fig. 1. The number of examples under ribbon cores is so great that only a few common forms are illustrated.

Measurements of Radiator Cores

The cooling capacity of a radiator depends chiefly on the core, since the water-tanks have relatively little effect. Correct measurements of the core are therefore of importance in determining its capacity. The size of a radiator is expressed by the frontal area and the depth of the core. The combined area of the air passages through the core, called the free-air area, is a factor in its performance.

Average values of the free-air area of typical cores, expressed as percentages of the frontal area, are given in Table 1. It will be seen that the values range from 65 to 75 per cent for all cores; hence the free-air area is a fairly large percentage of the frontal area, and is nearly constant for all types of core.

The capacity of a radiator is closely connected with the total amount of surface exposed to the air currents. This measurement, like the free-air area, is determined by the mensuration of the core, and is usually expressed in two parts. The surface enclosing the water channels is called the direct surface, and is assumed to be more effective, since it is in direct contact with the hot water. The remaining surface, consisting of fins or ribs, receives heat by conduction and is called the indirect surface. When the term surface is mentioned without qualification, it refers to the total or sum of the direct and the indirect surfaces. The surfaces of different cores can be compared only when they have the same volume. The results of comparing several types of core are given in Table 1. The unit of comparison has been the surface of a core having a volume of 1 cu. ft. Fin-and-tube cores have about the same amount of surface as air-tube cores, or from 110 to 130 sq. ft. for each cubic foot of volume. Certain ribbon cores have about the same amount of surface, but some small-sized cell

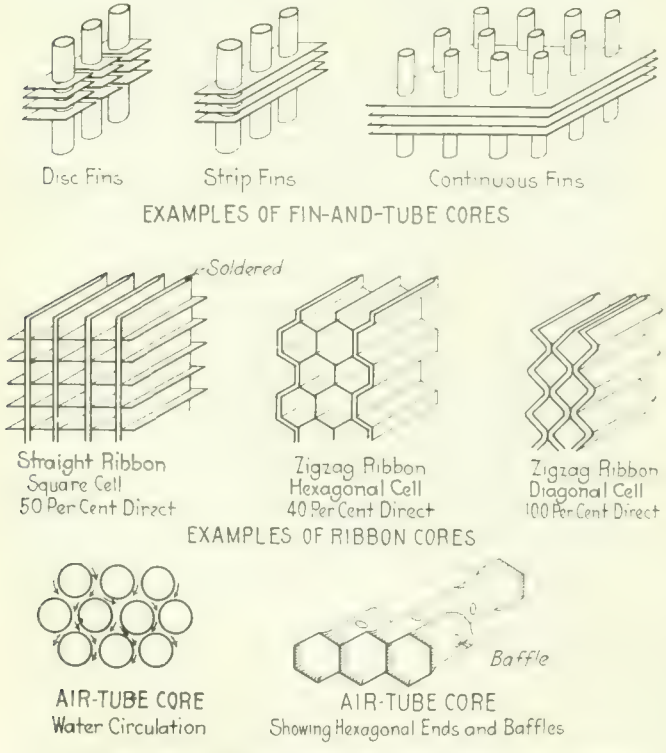


Fig. 1—Examples of the Three Types of Radiator Cores in General Use

Table 1—Average Values of Free-Air Area and Total Core Surface

Type of Core	Free-Air Area in Terms of Frontal Area, Per Cent	Direct Surface in Terms of Total Core Surface, Per Cent	Total Core Surface, for 1 Cu. Ft. of Volume, Sq. Ft.
Fin-and-Tube Disc Fins	57	16	110
Fin-and-Tube Continuous Fins	70	15	130
Ribbon Core	65 to 80	50	150 to 175
Ribbon Core	65 to 80	100	125
Air-Tube Core	72	100	110

cores with straight ribbons have a unit surface as large as 175 sq. ft.

The percentage of direct surface for the different types of core is given in Table 1. As stated above, it consists of a surface in contact with the water. The direct surface varies widely, being 100 per cent for air-tube cores and only 15 per cent for fin-and-tube cores. The values given in Table 1 are to be considered as general averages only. For use in computing any particular core the free-air area and core surface must be carefully measured.

Experiments on Cooling Capacity of Radiators

The heat dissipated by a radiator can be measured by supplying a known quantity of hot water at a constant temperature, and observing the drop of the temperature of the water for different air-velocities through the core. The apparatus requires some form of wind-tunnel, with means for adjusting the rate of air-flow. It also requires an ample water-supply at a constant temperature with means for metering and controlling the rate of flow. The experiments described were made on apparatus of this kind, where direct measurements were made at all temperatures, velocities, and the like. The air velocity was not measured directly, however, but was computed from the air temperatures by the thermal relations.

Comparison of the cooling capacity of two radiators requires identical air-velocities and identical temperatures of the entering water and the air. Since it is practically impossible to maintain these conditions constant, to make a comparison it is necessary to make a final reduction to a common basis. Formulas for this coefficient to the other radiator test-data are given in the Appendix. The starting point for this theory was the assumption that the rate at which heat leaves the surface is proportional to the difference in temperature between the metal and the air. The defect of the theory is that it takes no account of the effect of the velocities of the air and the water; hence these two variables must be dealt with independently, as will be shown in the next paragraph.

Heat-Transfer Coefficients

The theory of the transmission of heat from water to air through a thin metal wall involves the rate at which the heat is transferred from the wall or surface. The rate of transfer is expressed by the heat-transfer coefficient which is defined as the number of heat units per hour that will pass from one square foot of surface per degree of temperature-difference between the water and the air. In the case in which the temperature of both the water and the air changes in passing through the radiator, the arithmetical mean of the entrance and exit temperatures is taken. The relation of the heat-transfer coefficient to the other radiator test-data is given in the appendix, where formula (1) is used for computing the coefficient.

When a radiator is tested, a series of runs is made covering the desired range of air and water velocities, for each of which the heat-transfer coefficient is computed. The radiator performance is then estimated, not from the tests, but from the computed quantities found by the aid of the coefficients. It is desirable to plot the coefficients on cross-section paper so that inconsistent or erroneous results can be detected and the intermediate values interpolated.

An example of the heat-transfer coefficients for a ribbon core is given in Fig. 2. It is apparent that the coefficients are not constant, but increase with both the water and the air velocities. Similar diagrams have been made for other types of radiator, for each of which values have been interpolated for the same velocities, forming the new diagram shown in Fig. 3.

Six cores have been chosen as fairly representative of the three main types. The effect of high and low air-velocities is clearly shown by the right and the left sides of the diagram. At low air velocity the air-tube and the

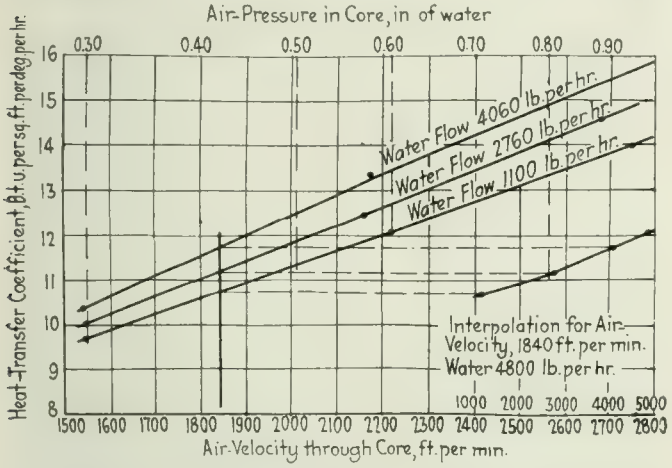


Fig 2 —Heat-Transfer Coefficients Showing the Variation Produced by Changes in the Flow of Air and Water

ribbon cores are about on a par. At high air-velocity the air-tube surface is more effective than the ribbon core. In both cases the fin-and-tube surface is inferior to either of the others.

Comparison of Cooling Capacity

When the heat-transfer coefficients have been found for a sufficiently wide range of water and air-flows, the cooling capacity of a radiator can be computed for any given condition. It is scarcely too much to say that the coefficients are a key to the radiator performance, for by their aid almost any desired information can be had. A useful expression for cooling capacity is given in the appendix, formula (6). It requires as given data: the initial water-temperature, t_1; the initial air-temperature, t_2; the rate of water-flow, w; the rate of air-flow, W; the core surface, S; and the heat-transfer coefficient, k. The air-flow rate must be computed by formula (2), using the assumed air-velocity and free-air area of the core. In comparing the cooling capacity of the two radiators, it is necessary to assume the same frontal-area and core-depth, as well as equal temperatures and velocities.

The foregoing method has been applied to the six cores whose heat-transfer coefficients were given in Fig. 3. The cooling capacities are given in Fig. 4, where the results are arranged in the same general way as in the preceding diagram. In comparing the two diagrams, it must be remembered that the heat-transfer coefficient takes account only of the quality of the surface for heat

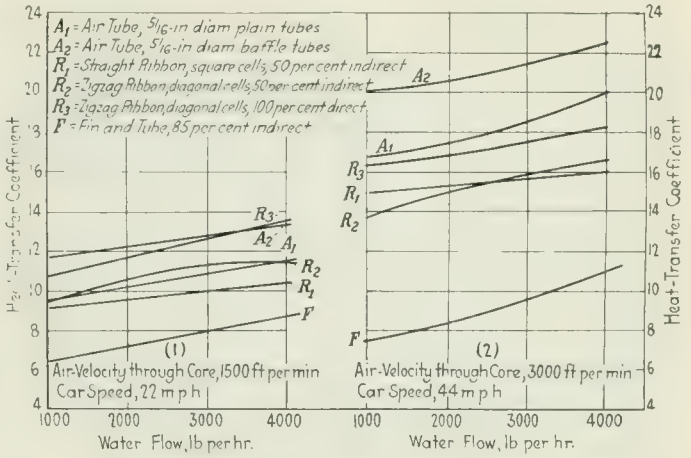

A1 = Air Tube, 5/16-in diam plain tubes
A2 = Air Tube, 5/16-in diam baffle tubes
R1 = Straight Ribbon, square cells, 50 per cent indirect
R2 = Zigzag Ribbon, diagonal cells, 50 per cent indirect
R3 = Zigzag Ribbon, diagonal cells, 100 per cent direct
F = Fin and Tube, 85 per cent indirect
Heat-Transfer Coefficient
(1)
Air-Velocity through Core, 1500 ft per min
Car Speed, 22 m p h
(2)
Air-Velocity through Core, 3000 ft per min
Car Speed, 44 m p h
Water Flow, lb per hr.

Fig. 3—Comparative Heat-Transfer Coefficients for Different Cores

exchange, but not its extent. On the other hand, the capacity diagram takes account of both the quality and the extent of surface of each core; hence it is a true measure of its cooling ability.

Fig. 4 suggests several interesting conclusions, which may be stated as follows:

(1) As between ribbon and air-tube cores as classes, there is little to choose for the speeds used in automobiles. For low air-velocity, ribbon cores are slightly better. For higher air-velocity the results are about on a par

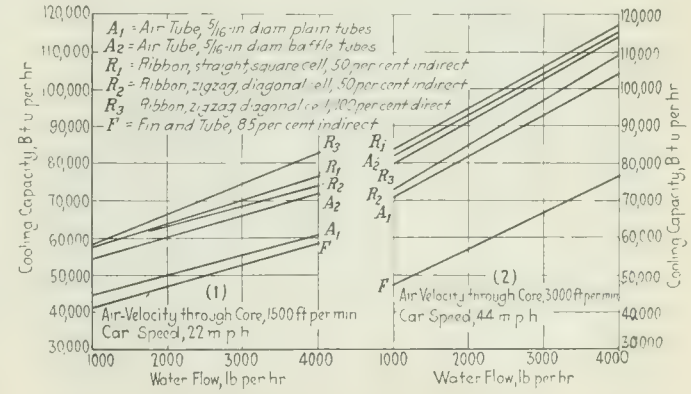
(2) The baffles, or dents, used in air-tube cores add materially to the cooling, without increasing the surface or weight

(3) The straight-walled ribbon core, having small square cells with 50 per cent of indirect surface, cools as well as other ribbon cores with 100-per cent direct surface. This result is partly due to the greater amount of surface possessed by the small cell core, but it also indicates that the indirect surface of this type of core is nearly equal to the direct surface in cooling ability

(4) The fin-and-tube core has only about three-quarters of the cooling capacity of the best forms of ribbon core of the same size. This is not surprising in view of the large amount of indirect surface contained in the fin-and-tube type

Thermo-Syphon Cooling

That the capacity of a radiator is greatly lessened by reduced water-flow has been shown clearly by Fig. 4, where the rates of flow vary from 1000 to 4000 lb. per hr. The heat exchange in thermo-syphon cooling can be computed by formula (7) of the appendix. This formula differs from formula (6) by omitting the water-flow, w,


A1 = Air Tube, 5/16-in diam plain tubes
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R2 = Ribbon, zigzag diagonal cell, 50 per cent indirect
R3 = Ribbon, zigzag diagonal cell, 100 per cent direct
F = Fin and Tube, 85 per cent indirect
Cooling Capacity, B.t.u. per hr
(1)
Air-Velocity through Core, 1500 ft per min
Car Speed, 22 m p h
(2)
Air-Velocity through Core, 3000 ft per min
Car Speed, 44 m p h
Water Flow, lb per hr

Fig. 4—The Cooling Capacity of Typical Radiator Cores

and substituting the exit temperature t_2. Otherwise it is used in the same way as formula (6), but it has one drawback in that the value of the heat-transfer coefficient depends on the water-flow; hence it cannot be interpolated in advance from the diagram. This drawback can be overcome by a trial computation with an estimated value, from which an approximate water-flow can be had, and from it a revised value of the coefficient.

In comparing pump and thermo-syphon cooling, the water-temperature drop can be assumed in each case, such as 200 to 185 for the pump and 200 to 150 deg. fahr. for the thermo-syphon. For the fin-and-tube core of Fig. 3, with water-flows of 1000 and 4000 lb. per hr., the heat-transfer coefficients may be assumed to be 6.4 for thermo-syphon and 8.7 for pump, both for an air-velocity of 1500 ft. per min. The fin-and-tube core in question has a core width of 19.00 in., a depth of 2.50 in., a frontal area of 2.24 sq. ft., a cooling surface of 62.00 sq. ft., and a free-air area of 1.57 sq. ft. From these values the weight of air, as found by formula (2), is $W =$ 10,200 lb. per hr. In solving formula (7) the air temperature is assumed to be 70 deg. fahr., and the water temperatures, as stated above, 200 to 185 and 200 to 150 deg. fahr.

For the pump, $H = 60{,}000$ B.t.u. per hr.
For the thermo-syphon, $H = 39{,}000$ B.t.u. per hr.

By formula (9) the water circulation found for each case is,

For the pump, $w = 4000$ lb. per hr.
For the thermo-syphon, $w = 780$ lb. per hr.

As the water-flows agree well enough with those assumed in estimating the heat-transfer coefficients, it is not necessary to choose new values, and the values of H may be assumed to be correct.

From these figures the cooling of thermo-syphon cores may be taken as about two-thirds of that for pump circulation, and the water circulation as about one-fifth as fast. These figures are based on an arbitrary temperature-drop in the radiator, and may be revised to suit the existing data. They are offered as showing a method of dealing with thermo-syphon circulation in a rational way. It is likely that the temperature-drop may be much less than that assumed, as an active circulation may be kept up by the steam-bubbles in the pipe leaving the cylinders, even with the water at nearly a constant temperature.

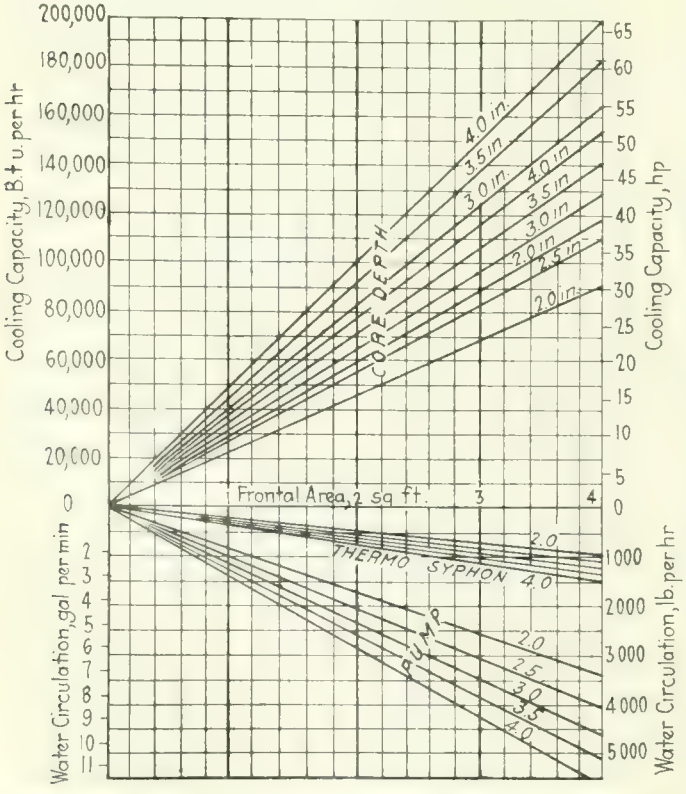

Fig. 5 Chart Showing the Cooling Capacity for Various Frontal Areas and Depths of Core

Cooling-Capacity Charts

The computed results for a radiator core may be put in convenient form for use as shown in Fig. 5. The frontal area is laid off on the horizontal center-line, with the cooling capacity above and the circulating water below. Each core-depth is marked on a sloping line, the heavy lines for the pump and the light lines for the thermo-syphon circulation. The cooling capacity is given in two units, the heat units on the left axis and the engine horsepower on the right. The two units are connected by the relation that the cooling required by 1 engine hp. is 3000 B.t.u. per hr. This figure is an arbitrary one but is believed to give sufficent cooling for automobile engines.

In constructing charts such as these it is necessary to assume limiting temperatures of the water and the air. In Fig. 5 the water temperatures were taken as 200 to 180 for pump circulation, and 200 to 140 deg. fahr. for thermo-syphon circulation. The air temperature was assumed to be 80 deg. fahr. The core air-velocity was assumed to be 1840 ft. per min., corresponding to about 25 m.p.h. Since all the lines are straight and pass through the origin, it is necessary to compute only one point by the formulas; thus the labor of constructing the diagram is reduced. The water rate for thermo-syphon circulation has no practical value, but was added to the chart because of its general interest. The chart may be used to determine the size of radiator suitable for a given engine, subject to the assumptions made. For example, a 50-hp. engine with pump circulation requires a core of 4-in. depth and 3-sq. ft. frontal area, and the engine pump must handle 9 gal. of water per minute.

Limiting Values of Core-Depth

The cooling capacity of a radiator can be increased by adding to its depth, without changing the frontal area. The increased depth will be accompanied by a proportionate increase of the cooling surface and the quantity of circulating water, but no change in the air-flow. It follows that, although the capacity will increase with the depth, it will do so in a diminishing ratio, and will reach a limit where no further increase of the depth will be justified.

The limits of core-depth can be worked out from formula (8) which is given in the Appendix. In applying formula (8) it is necessary to assume initial and final values for the temperatures of both the water and the air. This can be done inasmuch as the water temperature-drop is to be constant for all depths, say from 200 to 180 deg. fahr., and the air temperature is to rise to a fixed limit, which may be put at 120 deg. fahr., from an initial temperature of 70 deg. fahr.

To illustrate, a ribbon core has a frontal area of 2.21 sq. ft.; a free-air area of 1.42 sq. ft.; a surface, for 1-in. depth, of 19.00 sq. ft. Tests of this core showed a heat-transfer coefficient, $k = 15.0$ for 2.875-in. depth, at a velocity of 2900 ft. per min. through the core.

The temperatures for use in (8) are: $t_1 = 200$ deg. fahr.; $t_2 = 180$ deg. fahr.; $t_3 = 70$ deg. fahr.; $t_4 = 120$ deg. fahr.; $M = 19$; $k = 15$. W is to be computed from

appendix formula (2), using the air-velocity and free-air area given above, whence $W = 17{,}800$ lb. per hr.

Substituting in (8), the value of d is found to be 7.9 in., which is the proper depth of core for the limiting conditions imposed.

The cooling capacity for the limiting depth is computed by formula (4) as 213,000 B.t.u. per hr. The required water-flow is given by formula (9) as 10,650 lb. per hr., or 22 gal. per min.

Deep cores are required only when high air-velocities are supplied. For example, in the core just described, if the velocity be reduced to 1800 ft. per min. with the corresponding value of $k = 13.0$, the depth is found by (8) to be $d = 5.7$ in.

In the preceding computations it has been assumed that the heat-transfer coefficient varies with the air and the water velocities, but not with the change in the depth of core. The coefficient probably varies slightly with the core depth; hence some error may be introduced by this assumption.

Radiators for Steam Condensation

In steam automobiles it has been found convenient to utilize the radiator to condense the steam, which is then available for feeding to the boiler, thus avoiding the frequent filling of the supply tank. The cooling capacity of the radiator when condensing the steam can be found in the same way as when cooling the jacket-water. It is necessary only to modify formula (7) by making $t_1 = t_2 =$ 212 deg. fahr. The value of the heat-transfer coefficient, k, is found as for hot water with the most rapid circulation. Radiators of the fin-and-tube type are most durable for steam where superheat is sometimes found in the exhaust.

The application of radiators to the condensing of steam can be illustrated by an example, in which the brake horsepower will be assumed to be 20. The steam consumption per hour will be about 20 x 15, or 300 lb. To condense this steam will require approximately 1000 B.t.u. per lb., or 300,000 B.t.u. per hr. It is pertinent to remark that if a 20-hp. engine had been used in a gasoline car, the heat removed from the jackets would be only 20 x 3000 or 60,000 B.t.u. per hr. This amount is only one-fifth of the heat removed in condensing the steam; hence it is safe to predict that the condenser for the steam car must be much larger than the radiator for the gasoline car.

In computing the size of radiator required, it will be well to select a considerable depth, say 5 in., for which the surface per square foot of frontal area will be 54 sq. ft., using the average values for fin-and-tube cores, Table 1. The free-air area may be assumed as 70 per cent of the frontal area and the air velocity through the area may be assumed to be 1840 ft. per min., corresponding to a speed of 25 m.p.h. The air-flow by formula (2) will be 5600 lb. per hr. The heat-transfer coefficient, k, according to Fig. 3 will be about 9.0.

Placing the above values in formula (7), the heat dissipated per square foot of frontal area is found to be 58,000 B.t.u. per hr. The frontal area required to condense the entire amount of steam will be 300,000 divided by 58,000, or 5.2 sq. ft., or the equivalent of 25 x 30 in. It will be interesting to compare these figures with the size of radiator used on the Stanley steam car in 1920, which was 23 x 23 x 5 in. Without doubt the condensing radiator of a steam car will be taxed more severely than the radiator for cooling the jacket-water of a gasoline car.

APPENDIX

A = the free-air area through the core
d = the depth of the core
H = the heat dissipated from the core
k = the heat-transfer coefficient computed by formula (1)
M = the surface of the core per inch of depth
S = the surface of the core
s = the specific volume of air at the mean temperature
t_3 = the temperature of the air entering the core
t_2 = the temperature of the water leaving the core
t_3 = the temperature of the air entering the core
t_4 = the temperature of the air leaving the core
V = the velocity of the air-flow through the core
W = the weight of the air circulating through the core
w = the weight of the water circulating through the core
0.24 = the specific heat of air at a constant pressure

Fundamental Formulas

$$k = [w(t_1 - t_2)] \div \{ S(\tfrac{1}{2}[t_1 + t_2] - \tfrac{1}{2}[t_3 + t_4]) \} \quad (1)$$

$$W = (60AV) \div s \quad (2)$$

$$H = w(t_1 - t_2) \quad (3)$$

$$H = 0.24\, W(t_4 - t_3) \quad (4)$$

$$H = \tfrac{1}{2}(t_1 + t_2 - t_3 - t_4)kS \quad (5)$$

The following formulas were derived from those given above by transformation

$$H = [0.48\, W(t_1 - t_3)] \div [1 + (0.48\, W/kS) + (0.24\, W/w)] \quad (6)$$

$$H = \{ 0.48\, W[\tfrac{1}{2}(t_1 + t_2) - t_3] \} \div [1 + (0.48 W/kS)] \quad (7)$$

$$d = [0.48\, W(t_4 - t_3)] \div [kM(t_1 + t_2 - t_3 - t_4)] \quad (8)$$

$$w = H/(t_1 - t_2) \quad (9)$$

$$t_2 = t_1 - (H/w) \quad (10)$$

$$t_4 = t_3 + (H/0.24\, W) \quad (11)$$

TAXATION ON A TIRE CONSUMPTION BASIS

MOTOR-VEHICLE taxation should be directly proportional to the inflicting of damage upon the road. Statistics should be compiled to determine where and why and how damage is done to the road, where true economy lies and where waste is created. A flat method of taxation for all cars, with the result that whether a car covers in one year 1000 or 100,000 miles, the tax on both would be identical in amount, should not be followed. The only way to redress this unfairness is to shift the burden of taxation from the vehicle to the accessories that allow it to function. In other words, the tax must be moved back to the fuel or to the tires that record the business done by the cars shod with them. The latter seems to be the simpler expedient, and is fairer and easier to administer.

Tires cannot be used for anything but their legitimate purpose and every automobile owner must buy them. Their existence varies with the distance they cover, the rate at which they are revolved and the way in which the cars upon which they are mounted are driven. The more damage a tire does to a road, the sooner it is worn-out, and the earlier the owner has to find the money to make good the damage it inflicts. Of course, there are some parts of the country where the state of the roads is so bad that tires do not last as long as in more civilized districts, but, after all, one must pay for the luxury of living where there are good roads. Again an owner might have bad luck with one tire, but he can always change his brand. The plan would inspire the manufacture of better tires and teach drivers the virtues of carefulness and road sportsmanship.

It should not be difficult to fix such a tax. It should not vary altogether with size, but be based more on a section than on a circumference basis.—*Autocar.*

HARDWOOD LUMBER STANDARDIZATION

DURING the past fall the project of establishing new standards for the methods of grading hardwood lumber for all hardwood consuming industries was first brought to the Society's attention by the Hardwood Manufacturers' Institute in Chicago with the object of securing the cooperation of the Society as the national engineering body for the automotive industries, in carrying through this project to a successful termination. It was thought better at that time to learn more of the project before attempting to establish an organization within the Society to consider this work. It was considered, however, that probably the best method of handling it would be through the Passenger-Car Body Division of the Society's Standards Committee. Subsequently, the members of this Division were written to in this connection and the subject scheduled for discussion at the meeting of the Division in Detroit on Nov. 2, to which F. F. Murray, advisory mechanical engineer of the Hardwood Manufacturers' Institute, was invited to address the members.

He outlined the hardwood production situation and described the Institute's part in the general lumber standardization project that was largely inspired and sponsored by Secretary Hoover of the Department of Commerce, and by the National Lumber Manufacturers' Association.

Mr. Murray said:

> The Hardwood Manufacturers' Institute is national in scope, its membership comprising strictly hardwood producers and saw-mill operators whose output represents about 35 per cent of all hardwood lumber produced in the United States.
>
> Standardization of lumber sizes and cutting-up sizes for various purposes and of improved grading specifications is a problem requiring the cooperative effort of the producers and consumers, and the Hardwood Manufacturers' Institute is endeavoring to establish that cooperation with the consumers to remedy the admittedly unsatisfactory conditions that now prevail.
>
> The consumers of hardwood lumber are not alone in their complaint as to conditions within the hardwood industry as they exist to-day, as the producers suffer likewise. The cardinal purposes of the Institute are to secure adequate standardization for grading of hardwood lumber, guaranteeing the quality of shipments and meeting the consumer's requirements as fully as possible; to obstruct misrepresentation in grading, grade substitutions and the many forms of trade practice that at the present time reflect seriously on the industry.
>
> The present methods of grading hardwood are inadequate. The top grade of "Firsts" and "Seconds" is determined by specifying a permissible number of defects in the boards; for example, in a board 15 in. wide and 16 ft. long, five standard defects such as 1¼-in. knots, etc., are allowed, without regard to the location or relation of those defects. Obviously the factory man is interested in what he can get out of the boards in the cut-up sizes he wants and in the quality he gets, not merely in the number of defects in the board.
>
> The project under study is based on general factory cut-up sizes in which requirements as to quality become the units of consideration instead of the entire board being the grading unit as at present.
>
> The present methods of grading were established over a quarter of a century ago, long before the general use of the automobile and the products of many other large and specialized consumers of hardwood lumber. The present rules have not been changed in hardly any particular since then and are obsolete and inadequate in view of the tremendous developments in the hardwood consuming industries.
>
> A thorough study is necessary of the hardwod requirements of the major consuming industries, including furniture, automobiles and trucks, agricultural implements and many others, so that whatever new standards are developed will serve all of those industries to the best advantage.
>
> Lumber, unlike many other raw materials, is in a sense already manufactured by nature. The problem is to establish methods of grading and distributing so that each industry can get that part of the tree which it can use to the best advantage.
>
> This will eliminate unnecessary waste and provide a substantial saving to both consumer and producer aggregating many millions of dollars per year and the conservation of millions of feet of standing timber.
>
> The program also anticipates the building up of a satisfactory market for the lower grades of hardwood lumber, which, with prices based on supply and demand, will place the low grades in the scale with top grades and arrest the widening spread between top and intermediate or low grades of hardwoods. It is believed that therein lies the only answer to the complaint against high and increasing prices for top grades of hardwoods of which there is an actual scarcity in comparison with the lower grades.
>
> The general organization of the lumber standardization movement is centralized in the Central Committee on Lumber Standards, the organization of which was completed last October. This committee, having headquarters in the City of Washington, is an executive body representing the several branches of the lumber industry in its entirety. Ultimately the standards which the participating producer organizations develop in cooperation with the consuming industries will be grouped into a comprehensive American Lumber Standard.

Following Mr. Murray's address, discussion indicated that the body-building branch of the automotive industry is more interested in this project than any other one branch, although the motorboat, airplane, tractor and some more specialized branches of the industry are probably interested to a lesser extent. It was not felt by the members that the Society as such should endeavor to gather data and attempt to formulate standards covering the production of hardwood lumber but that the better method would be to organize a Subdivision to serve as a point of contact between the automotive industries and the Hardwood Manufacturers' Institute and to assist the Institute in an advisory capacity, providing a channel through which the Hardwood Manufacturers' Institute can obtain data if so desired. Mr. Murray stated that the view of the situation taken by the members of the Division was the same as that of the Institute and that such an organization representing the automotive industries would greatly assist in the successful completion of the program inasmuch as the automotive industry has grown to be one of the largest hardwood consumers.

George E. Goddard, chairman of the Passenger-Car Body Division, has appointed the following Subdivision to serve in this capacity.

George J. Mercer, chairman, Detroit
C. W. Avery, Ford Motor Co.
R. A. LaBarre, Towson Body Co.
F. F. Murray, Hardwood Manufacturers' Institute
Carl Simmons, Fisher Body Corporation

Inasmuch as this project will probably constitute a very important step toward the conservation of the available hardwood lumber resources of America and consequently tend toward a reduction in the cost of hardwood lumber, it is urged that all members of the Society representing hardwood consuming companies cooperate as fully as possible with the Society or the Hardwood Manufacturers' Institute when they are asked to furnish data and information regarding their hardwood lumber requirements.

An Experimental Survey of Gasoline and Kerosene Carburetion

By C. S. Kegerreis[1] and G. A. Young[2]

Annual Meeting Paper *Illustrated with* Photographs and Charts

REALIZING that great quantities of fuel are being wasted yearly by improper carburetion, the results of several investigations are assembled and considered from various viewpoints. Some pertinent data have been published previously; therefore, only a general discussion of gasoline carburetion requirements is presented in this paper. The scope of the paper is too broad to include a detailed discussion of any one subject. However, the data have been compiled to allow the graphs to explain many points that could not otherwise be touched.

The kerosene research is particularly valuable, not so much in outlining the requirements for burning kerosene as an automotive fuel exclusively, but for the carburetion requirements necessary in using our future petroleum fuels satisfactorily. Supposing that the future fuel will embody hydrocarbons boiling up to 550 deg. fahr. as a limit and containing sufficient volatile fractions to allow engine starting even in cold weather, the authors feel that kerosene will lie within the limits of efficient carburetion.

In addition to the ideal requirements, data are shown to prove the reasons for the present wastage of fuel. This is illustrated by the metering characteristics and allied data obtained from a few commercial carbureters, the data being used merely as a comparison with the ideal requirements. The change of temperature of fuel and air causes a change in the metering characteristics and the metering is not as desired. In addition, there are the temperature requirements of fuels that must be recognized, thus making the problem of carburetion truly complex.

IN the last few years our attention has been forced to center on the fuel problem more than on any other. The various aspects of this problem with respect to continued supply have been discussed thoroughly and are common knowledge to every automotive engineer. Therefore, the object of this paper is to avoid any discussion of the unmined supply of petroleum or how long it will last under the present rates of consumption, but rather to present data showing how well we can burn our present fuels and to estimate as correctly as possible some utilization requirements of our future fuels.

Formerly, satisfactory performance of our cars was easily obtained by the use of volatile fuels and, as the cost of the fuel was low, economy was of minor importance. With the advent of more than 10,500,000 cars and trucks in the United States, not including motorcycles and tractors, the situation is changed entirely. With the changing of the situation, other phases of the problem are introduced. Power is no longer paramount, being gradually forced to share its position with economy. The element of economy is now growing to be considered as essential as power. The price of gasoline is advancing steadily, yet we do not feel this to be the only reason for considering economical operation. Where power alone is concerned, too much trouble is experienced from carbon deposits, oil dilution and the cost of service and replacements due to the rich mixtures used. The United States has indeed been fortunate in securing refined fuels so easily and cheaply. However, a few years hence, when price will perhaps be the main consideration of the general public, fuel economy will be paramount.

The use of higher compressions in the throttling engines will improve economy wonderfully but, in spite of this fact, the loss due to improper mixture preparation for combustion must be eliminated to allow the best utilization. When estimated from the results of various tests, the loss of fuel in 1921 alone shows that 25 per cent of the gasoline consumed is absolutely wasted on account of improper carburetion and consequently poor combustion. The consequent $350,000,000 per year wasted would aid materially in meeting the following year's fuel bill, if conserved. Even this large sum does not indicate the total loss caused by improper fuel utilization in the United States. To the above value must be added the greater cost of service and replacements and an increased depreciation; thus, the total wastage will at least triple the above-mentioned amount. Certainly these estimates are sufficiently important for our consideration.

We must admit that the saturation point of the automotive industry is by no means attained. Viewing this fact in connection with our fuel resources, the only solution that seems practicable where the cost of the fuel is included is to refine a fuel embodying light fractions for starting and including the various hydrocarbons nearly up to the end-point of kerosene. We may not be justified in choosing a fuel of this type as the inevitable one but, when economy is considered in connection with the fuel costs, we feel the automotive industry will ultimately arrive at this conclusion.

With the increasing tendency toward heavier fuels, the automotive industry will be interested in the evaluation of some of the carburetion requirements. The Purdue Engineering Experiment Station has therefore made some researches on the subject of gasoline and kerosene carburetion. Some of the data have been presented before the Society by O. C. Berry, in his paper on Mixture Requirements of Automobile Engines,[3] and others have been published from time to time. In the present paper, additional results on gasoline are given and data on kerosene carburetion are included.

In making a study of carburetion we are interested in the ideal as well as the practical requirements. This investigation made, there will be some definite basis on which to design apparatus for the best performance with respect to the fuel in use. From another viewpoint, what metering characteristics are the various carbureters delivering to the engine? The results will show just how well our present-day devices are meeting engine requirements.

Up to the present, the researches have been confined to work on multi-cylinder engines of various types. The question of distribution in multi-cylinder engines is a

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[3] See The Journal, November, 1919, p. 364.

FIG. 1—DYNAMOMETER TESTING PLANT

complex problem but, when foggy or dry mixtures are induced through the average manifolds, a long stride is taken toward the solution. Since the industry is dependent on the multi rather than the single-cylinder engine, the results of this investigation are of immediate practical value.

The fuels used in the tests are the ordinary gasoline and kerosene sold at the service-stations for commercial use. The gasoline data cover the fuels used for the last 4 years, and Table 1 presents the distillation of the first fuel as well as the fuel in use now. The unsaturation content as determined by absorption in sulphuric acid is approximately 12 per cent for gasoline and 7 per cent for kerosene.

The plant on which the tests were made has been described in several publications, and its details will not be discussed at this time. Figs. 1, 2 and 3 show the entire dynamometer plant, including the fuel-weighing and electrical-control devices. All conditions were held as constant as possible, accuracy being one of the main features of testing. The data on the cooling loss probably contain the maximum error, as the heat capacity of the engine caused some lag.

TABLE 1—DISTILLATION OF FUELS USED

	Gasoline		Kerosene
Specific Gravity, deg. Baumé	56.5	56.5	41.2
Initial Boiling-Point, deg. fahr.	96	99	350
10 Per Cent Distilled, deg. fahr.	162	166	390
20 Per Cent Distilled, deg. fahr.	210	203	411
30 Per Cent Distilled, deg. fahr.	247	235	418
40 Per Cent Distilled, deg. fahr.	272	260	426
50 Per Cent Distilled, deg. fahr.	295	282	434
60 Per Cent Distilled, deg. fahr.	313	303	443
70 Per Cent Distilled, deg. fahr.	335	324	452
80 Per Cent Distilled, deg. fahr.	356	349	464
90 Per Cent Distilled, deg. fahr.	381	383	488
Maximum Per Cent Distilled, deg. fahr.	425	426	538

The tendency to supply less volatile fuels for the automotive industry has given rise to the question of the economy of such action. Can we obtain more car-miles per unit of crude petroleum by the use of a heavier fuel; and, if so, will the performance be satisfactory to the public? Ricardo states, in his Means of Materially Increasing Thermal Efficiency,[4] that he has made tests of about 40 fuels, and that the power and efficiency characteristics with respect to mixture strength are the same for all except alcohol. However, for satisfactory performance in an engine, the power and efficiency characteristics depend on the volatility of the fuel and hence the temperatures required for their utilization. Viewing the situation from this angle, the two fuels represented in Table 1 were tested in the same engine under the same throttle-opening and at the same speed. The pre-

[4] See *Automotive Industries*, Feb. 24, 1921, p. 456.

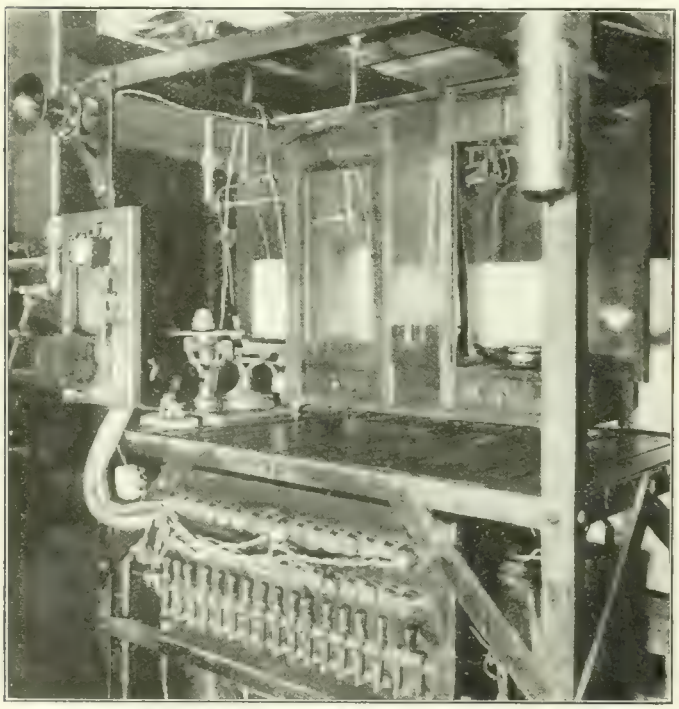


FIG. 2—FUEL-WEIGHING AND ELECTRICAL-CONTROL MECHANISM OF THE PLANT

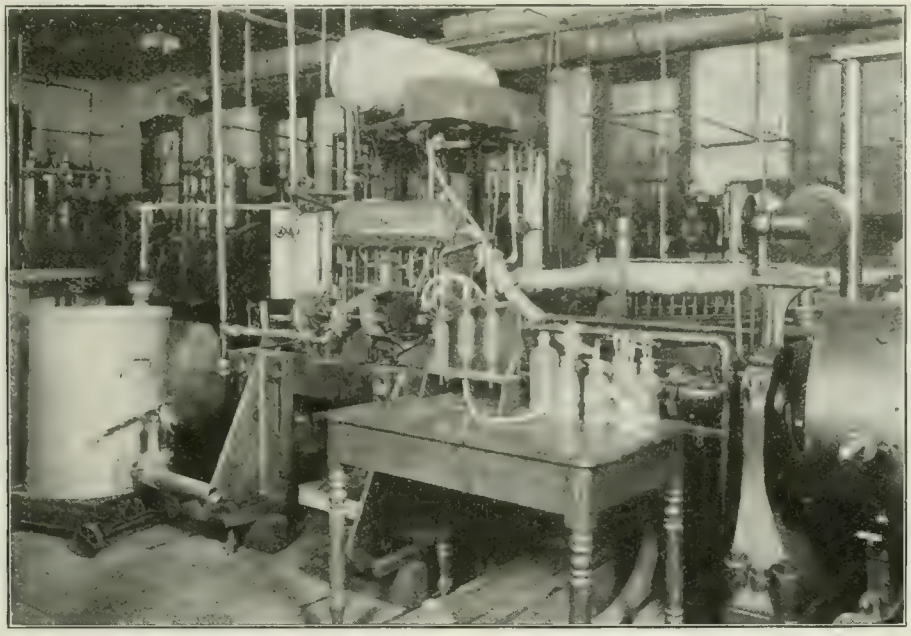


FIG. 3—THE OPPOSITE SIDE OF THE DYNAMOMETER TESTING PLANT

heated-air method was employed instead of the hot-spot in determining the proper temperature for carburetion. This method is superior for experimental research, be-

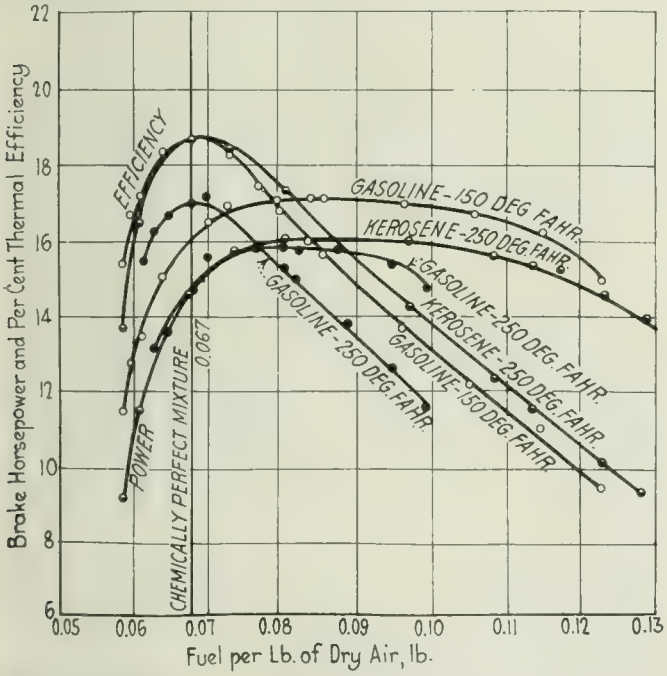


FIG. 4—POWER AND BRAKE THERMAL EFFICIENCY CHARACTERISTICS OF GASOLINE AND KEROSENE AT A CONSTANT THROTTLE-OPENING

cause of the more uniform vaporization and distribution and for the reason that the temperature can be controlled more readily. We wish to state, however, that the hot-spot is superior for practical usage in a correctly designed system of manifolding.

COMPARISON OF GASOLINE AND KEROSENE

The temperatures chosen for good performance are the minima required and allow some oil-dilution. The power and the efficiency of the two fuels are considered at this time; the temperature requirements will be discussed later in the paper. Fig. 4 presents the power and

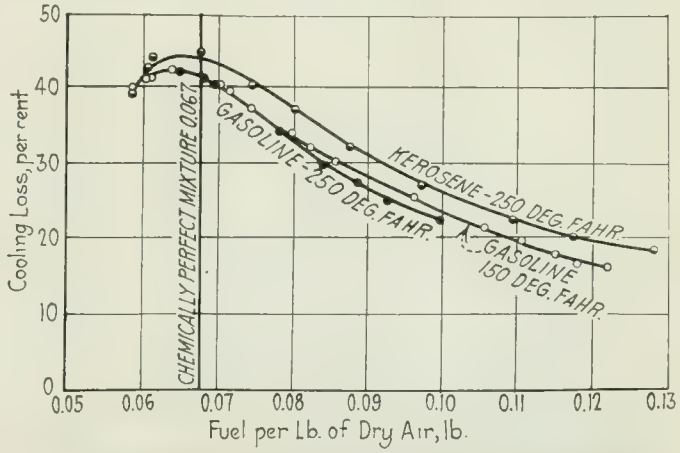

Cooling Loss, per cent
Fuel per Lb. of Dry Air, lb.
CHEMICALLY PERFECT MIXTURE 0.067
GASOLINE-250 DEG. FAHR.
KEROSENE-250 DEG. FAHR.
GASOLINE 150 DEG. FAHR.

FIG. 5—COMPARISON OF THE COOLING LOSSES FOR GASOLINE AND KEROSENE AT HALF LOAD

brake thermal-efficiency curves with respect to mixture strength. These data were taken from a four-cylinder Midwest engine of 4⅛-in. bore and 5¼-in. stroke. The gasoline-250 deg fahr. curves compare the two fuels at the same temperature; the mixtures for gasoline, how-

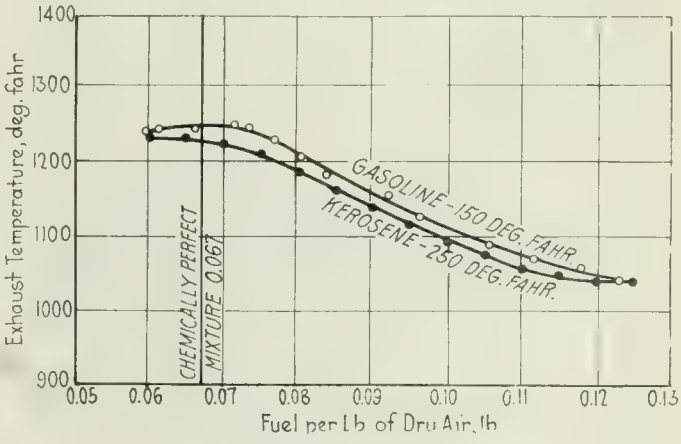

Exhaust Temperature, deg. fahr
Fuel per Lb of Dry Air, lb
CHEMICALLY PERFECT MIXTURE 0.067
GASOLINE-150 DEG. FAHR.
KEROSENE-250 DEG. FAHR.

FIG. 6—EXHAUST-GAS TEMPERATURES AT HALF LOAD FOR GASOLINE AND KEROSENE

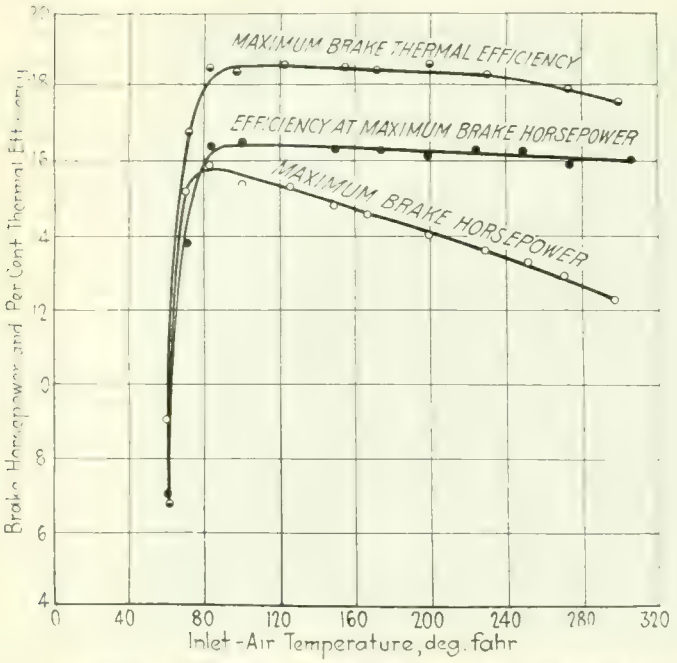


FIG. 7—EFFECT OF THE INLET-AIR TEMPERATURE ON THE POWER AND THE EFFICIENCY WHEN USING GASOLINE

ever, were nearly dry and those for kerosene fairly wet on entering the cylinder. Under the temperature requirements for good operation, the power developed by the lighter fuel is the greater by about 7 per cent under a maximum-power mixture-ratio. The thermal-efficiency curves show the opposite, 0.7 per cent greater for the kerosene fuel, and constant for all ratios richer than that of high power. It is interesting to note that the efficiencies coincide at the theoretically perfect mixture. At the same inlet-temperature conditions, the power is identical for the two fuels, but the efficiency for the gasoline drops consistently about 2 per cent throughout the mixture range for regular operation.

The comparison of the cooling loss made in Fig. 5 under the same conditions as for Fig. 4, shows very little difference for the two gasoline tests, but the kerosene series are 2.5 per cent higher. Fig. 6 gives the curves of the exhaust temperatures for the two fuels. In this

[5] See *Automotive Industries*, Sept. 29, 1921, p. 610.
[6] See THE JOURNAL, March, 1922, p. 171.

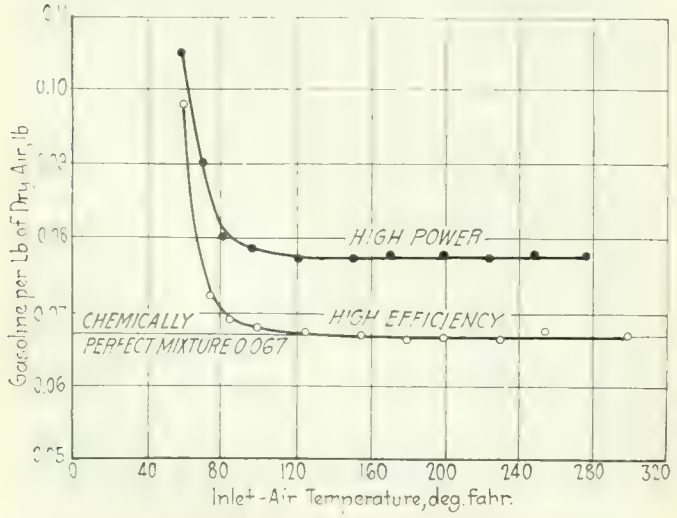


FIG. 8—MIXTURE-RATIOS REQUIRED AT VARIOUS INLET-AIR TEMPERATURES

instance, the average gas temperature is higher for gasoline than for kerosene. The temperatures were taken by thermocouples projecting into the exhaust-manifold at cylinder No. 1, between Nos. 2 and 3, and some distance beyond No. 4, through which region all the gases passed.

The results from these tests indicate that the heavier fuel does not develop as much power as the lighter, due to the increased temperature necessary for continued performance. The thermal efficiency, even under the higher temperatures, is as high or higher for the heavier fuel. From an economic standpoint of a continued supply and the price of the fuel, the heavier fuel is the better. It remains for the automotive engineer to develop carburetion systems to prepare the fuel properly for use in the engine.

GASOLINE CARBURETION

Since the results of some of the gasoline data compiled by the Purdue Engineering Experiment Station have been published previously, the main points only will be discussed and augmented by data in graphical form.

In the carburetion of any fuel, the four main factors linked to the metering characteristics are (*a*) the effect of the mixture temperature, (*b*) the effect of the speed, (*c*) the effect of the load, and (*d*) the effect of the compression. In all cases each fuel will require some definite temperature of air that will supply enough heat to allow good distribution and show high economy.

Fig. 7 presents data, showing the effect of inlet-air temperature on thermal efficiency and power, taken from an article entitled The Effect of Mixture-Ratio and Temperature on Power and Economy,[5] by C. S. Kegerreis. A critical point is located at 85 deg. fahr.; and below it the power output drops rapidly. Higher temperatures cause a power decrease due to a change of the volumetric efficiency, but the thermal efficiency is not affected greatly until the dry-point is nearly reached. Even though 85 deg. fahr. produces the highest power, the performance is not entirely good until 150 deg. fahr. is attained, because of the oil dilution and the uneven speed-regulation, the latter being a function of the manifold distribution. Another check on an entirely different powerplant also establishes 150 deg. fahr. as the minimum. In taking exhaust-gas temperature-measurements with respect to the inlet air at a given power, the gas temperature becomes nearly the minimum at 150 deg. fahr. and remains fairly constant up to the dry-point of the mixture, as was brought out in the paper[6] presented by O. C. Berry and C. S. Kegerreis at the 1922 Annual Meeting of the Society. This shows that the degree of heat in the air must be sufficient for good combustion, as below this critical point the exhaust temperature rises rapidly.

Taking a different viewpoint for the preceding tests, Fig. 8 presents the mixture requirements for temperature at half load.[5] The graphical results for high power and for high efficiency call for richer ratios at air temperatures of less than 125 deg. fahr.; thus, at 150 deg. fahr., the mixtures are as lean as possible for power and efficiency. Summing the results from these three viewpoints and from different engines, an inlet-air temperature of 150 deg. fahr. is the minimum that it is wise to maintain.

The limits of regular firing or inflammability are of interest. As the air temperature is decreased below 100 deg. fahr., the limits narrow abruptly,[5] as shown in Fig. 9. The leanest mixture for regular operation with wet fuel is about 150 deg. fahr. The constancy of this lean

limit under good performance temperatures signifies that the distribution is fairly uniform.

Additional information on inflammability is given in Fig. 10 for two temperatures with respect to the load. In fact, the 150 and 300-deg. fahr. series represent the low and high limits that include good operation; that is, the lower temperature represents the wettest mixture

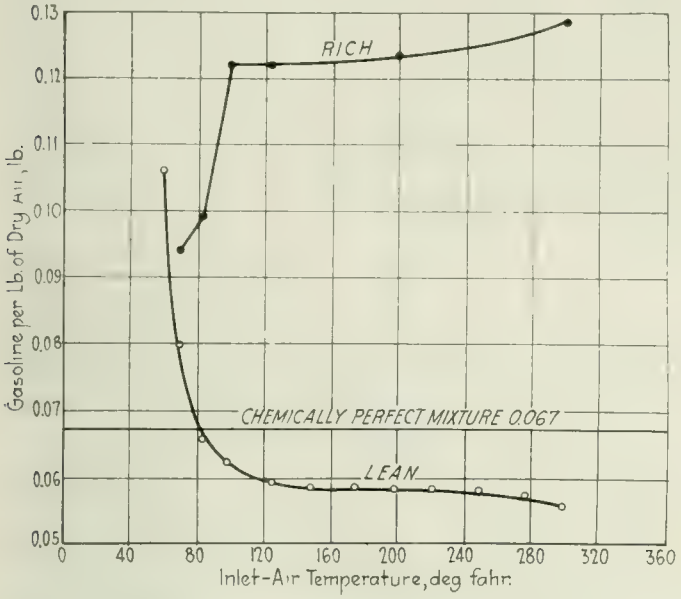


FIG. 9—THE LIMITS OF INFLAMMABILITY AT VARIOUS INLET-AIR TEMPERATURES

desirable for use, and the higher, the approximate point of dry mixtures. The dry mixtures allow better distribution by being more homogeneous, and the engine is therefore enabled to fire the poorer mixture-ratios. The effect of the load can be noted readily by comparing the

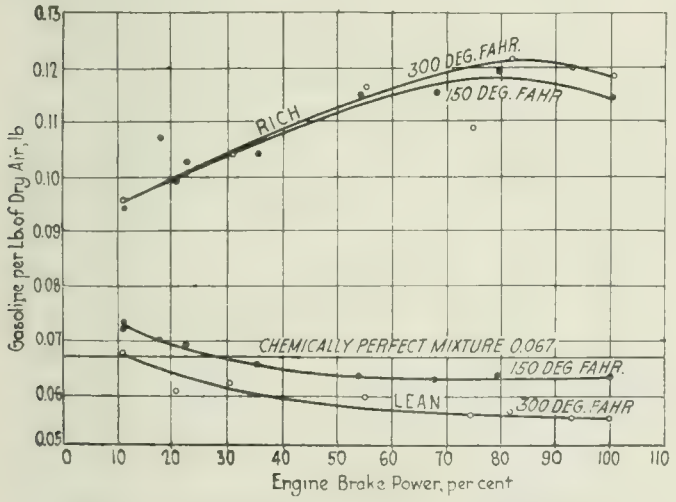


FIG. 10—THE EFFECT OF THE LOAD ON THE LIMITS OF INFLAMMABILITY

mixture-ratios required at low and high loads. At 10-per cent brake-load, a ratio of 0.072 is necessary at the lower temperature, due no doubt, to a less concentrated charge and poorer scavenging. Data from another engine are shown in Fig. 11, illustrating the effect of the speed at the different loads. A point worthy of mention in connection with regular firing is the rich mixture required for about 10 per cent brake-load at the lean limit. In fact, the engine developed nearly the maximum results

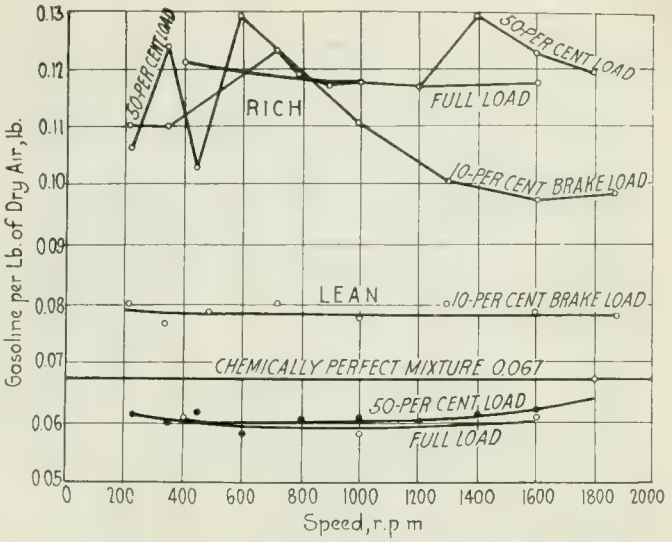


FIG. 11—THE EFFECT OF THE SPEED ON THE MIXTURES FOR REGULAR INFLAMMABILITY

when using this ratio, regardless of occasional misfiring. Manifolding is a factor in this case, as well as the mechanical condition of the engine; for example, valve-stem

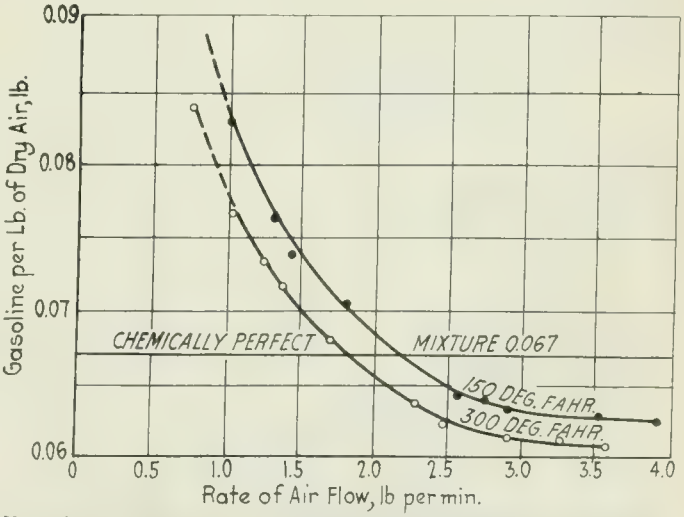


FIG. 12—THE MIXTURE-RATIOS REQUIRED FOR MAXIMUM EFFICIENCY AT VARIOUS LOADS, EXPRESSED IN AIR-FLOW RATE

wear, gasket tightness and the like. The higher loads, at any speed tested, show nearly the same ratios for all engines studied.

The effect of the load and the speed on the mixture requirements for gasoline follow certain definite relation-

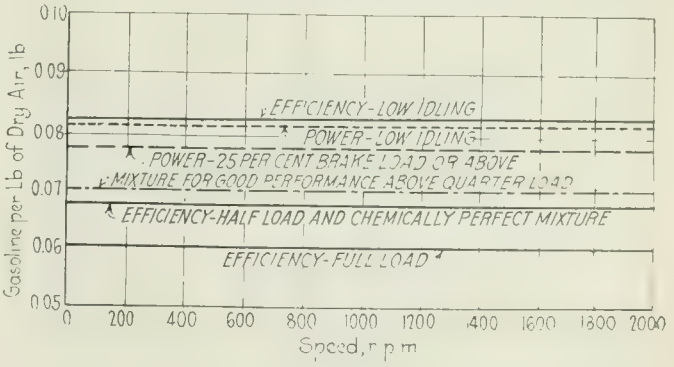

EFFICIENCY-LOW IDLING
POWER-LOW IDLING
POWER-25 PER CENT BRAKE LOAD OR ABOVE
MIXTURE FOR GOOD PERFORMANCE ABOVE QUARTER LOAD
EFFICIENCY-HALF LOAD AND CHEMICALLY PERFECT MIXTURE
EFFICIENCY-FULL LOAD
Gasoline per Lb. of Dry Air, lb
Speed, r.p.m.

FIG. 13—THE MIXTURE-RATIOS REQUIRED FOR GASOLINE AT VARIOUS LOADS AND SPEEDS

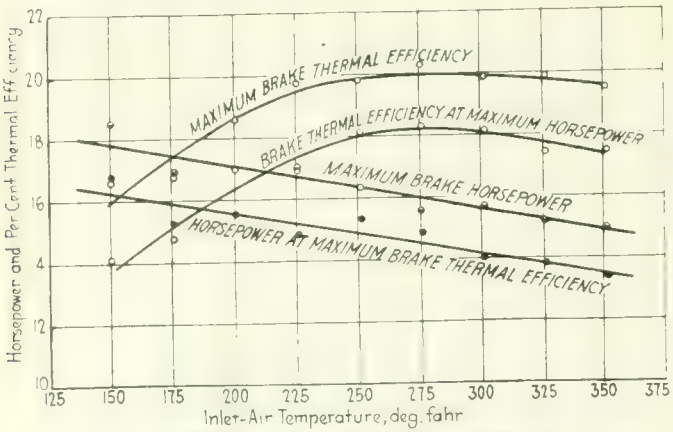

MAXIMUM BRAKE THERMAL EFFICIENCY
BRAKE THERMAL EFFICIENCY AT MAXIMUM HORSEPOWER
MAXIMUM BRAKE HORSEPOWER
HORSEPOWER AT MAXIMUM BRAKE THERMAL EFFICIENCY
Horsepower and Per Cent Thermal Efficiency
Inlet-Air Temperature, deg. fahr

FIG. 14 —THE EFFECT OF THE INLET-AIR TEMPERATURE ON THE ENGINE CHARACTERISTICS WHEN USING KEROSENE

ships, as shown in Figs. 12 and 13. An example pointing out the requirements of efficiency for any change of the load is found in Fig. 12, where the flow of air represents the load at a constant speed. The curve representing mixture-ratio versus flow-rate is of a hyperbolic form and can be represented by the general equation

$$M = C + K/F$$

where

C = an equation constant
F = the flow-rate in pounds of air per minute
K = an equation constant
M = the mixture-ratio in pounds of fuel per pound of dry air

[7] See *Automotive Industries*, Feb. 24, 1921, p. 460.
[8] See THE JOURNAL, June, 1921, p. 553.

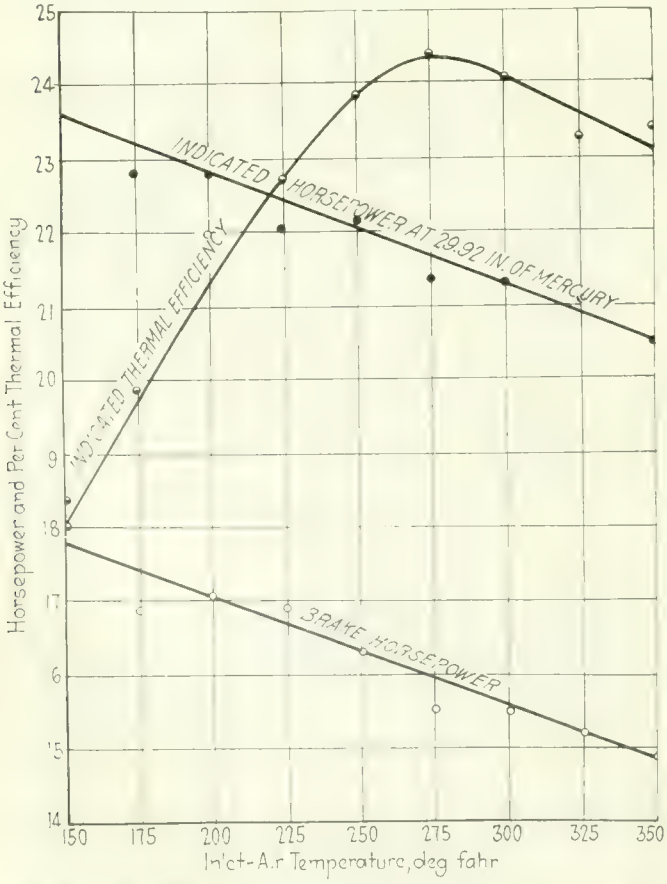

INDICATED HORSEPOWER AT 29.92 IN. OF MERCURY
INDICATED THERMAL EFFICIENCY
BRAKE HORSEPOWER
Horsepower and Per Cent Thermal Efficiency
Inlet-Air Temperature, deg. fahr

FIG. 15—THE EFFECT OF THE INLET-AIR TEMPERATURE ON THE POWER AND THE EFFICIENCY IN TERMS OF THE INDICATED RESULTS

For the test series at 150 deg. fahr., the equation assumes the form

$$M = 0.0545 + 0.0283/F$$

and, at 300 deg. fahr. or for the dry mixtures,

$$M = 0.0553 + 0.0210/F$$

The effects of the load and the speed are shown in Fig. 13. The high power-ratio for variation of the load changes slightly, the richer mixture, 0.0815, being required at the low load. As the load is increased, the ratio becomes constant at approximately 25-per cent brake-load and its value is 0.0775 lb. of gasoline per lb. of dry air. Formerly, it was thought a constant ratio sufficed; but the change in the mixture-ratio, due to the variation of mechanical accuracy in engines and to scavenging, makes a small change necessary.

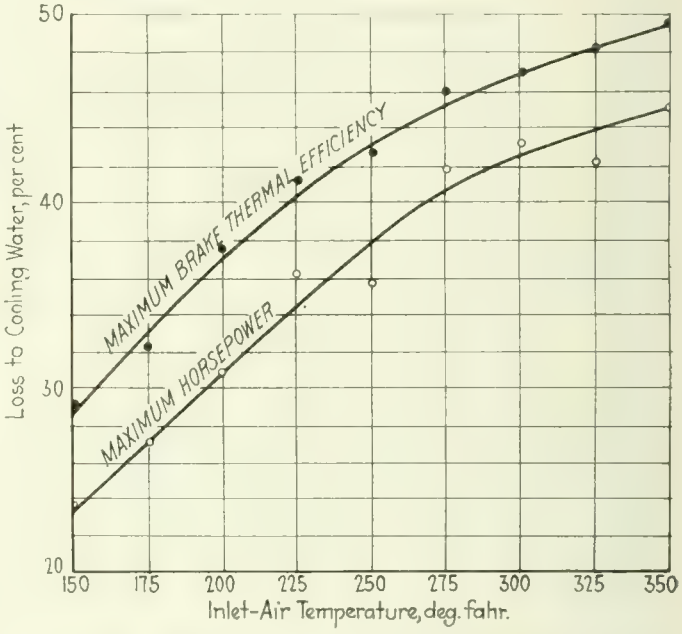


FIG. 16—THE EFFECT OF THE CARBURETION TEMPERATURES ON THE ENGINE COOLING LOSS

The effect of the speed on the mixture-ratio is nil under good temperature conditions up to the maximum speed attained, 2000 r.p.m. With correct carbureter and engine design, the higher speeds should not affect the constant ratios required.

The remaining factor, compression, with its influence on mixture-ratio requirements, is not determined so conclusively. Ricardo states that for all fuels, with the exception of alcohol, the mixture strength is not affected by compression.[7] Sparrow relates, "A recent series of tests at the Bureau of Standards has shown that, with an aviation engine having compression-ratios of 5 to 3, 6 to 3, 7 to 3 and 8 to 3, the maximum power was obtained with air-fuel ratios of from 13 to 1 (0.0770) to 14 to 1 (0.0714) with air densities of from 0.025 to 0.075 lb. per cu. ft. This was, however, with aviation gasoline, a more volatile product than commercial fuel."[8] Fragments of data from other sources show a tendency toward the poorer mixture-ratios at the higher compressions. It is reasonable to maintain that the more concentrated the charge is, the less will be the fuel necessary in the mixture for the maximum power development.

KEROSENE INVESTIGATIONS

In dealing with kerosene as a fuel, the same factors must be evaluated in the same manner as with gasoline. The temperatures for satisfactory operation must first be

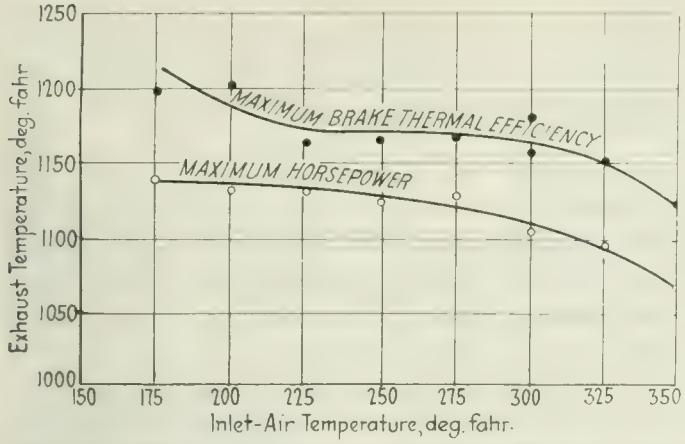


FIG. 17—THE REGISTER OF THE EXHAUST TEMPERATURES FOR VARIOUS INTAKE TEMPERATURES

determined. Since the volatility of kerosene is lower than that of gasoline, the temperatures required for good power and efficiency development will be relatively higher. With the same throttle-opening Fig. 14 presents the effect of the air temperature on the power and the thermal efficiency. Kerosene at one-half load will develop higher power at 150 deg. fahr. than at any higher temperature, even though the engine operation is very erratic and the oil dilution excessive. The thermal efficiency proves the poor operation at such low temperatures. Maximum brake thermal-efficiency occurs at 275 deg. fahr.; and the indicated thermal-efficiency occurs at the same point as shown in Fig. 15. Considering power and economy, temperatures lower than 250 deg. fahr. should not be used and,

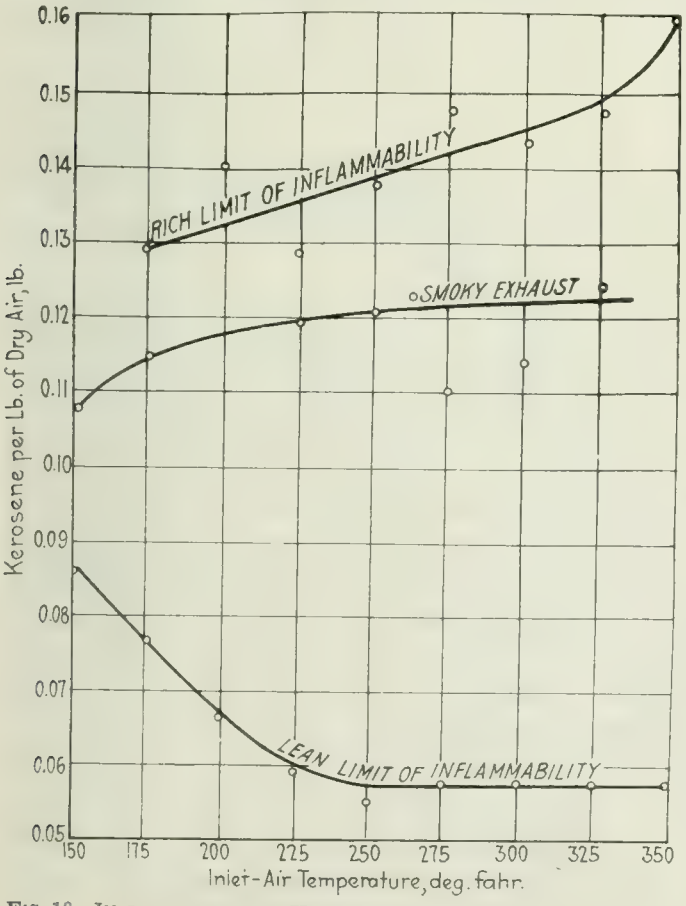

RICH LIMIT OF INFLAMMABILITY
SMOKY EXHAUST
LEAN LIMIT OF INFLAMMABILITY
Kerosene per Lb. of Dry Air, lb.
Inlet-Air Temperature, deg. fahr.

FIG. 18—INFLAMMABILITY OF KEROSENE-AIR MIXTURES WITH RESPECT TO THE INLET TEMPERATURE

in view of the excessive oil-dilution, this is only too true.

Some details of the cooling loss and the exhaust-gas temperatures are plotted in Figs. 16 and 17. The percentage of cooling loss with respect to inlet-air temperature mounts as a straight line up to 250 deg. fahr.; at this point the slope of the curve begins to break, resulting in lower heat-loss per unit of air-temperature increase. The inlet and outlet jacket-water was maintained at a constant temperature throughout the tests, the outlet-water temperature being 150 deg. fahr. The register of the average exhaust-temperatures, shown in Fig. 17, is given for the mixture-ratios corresponding to the maximum brake thermal-efficiency and brake horsepower.

The limit of inflammability is another point worthy of consideration in proving more completely the optimum temperature for engine performance. The lean limit of regular firing breaks into a straight line at an air tem-

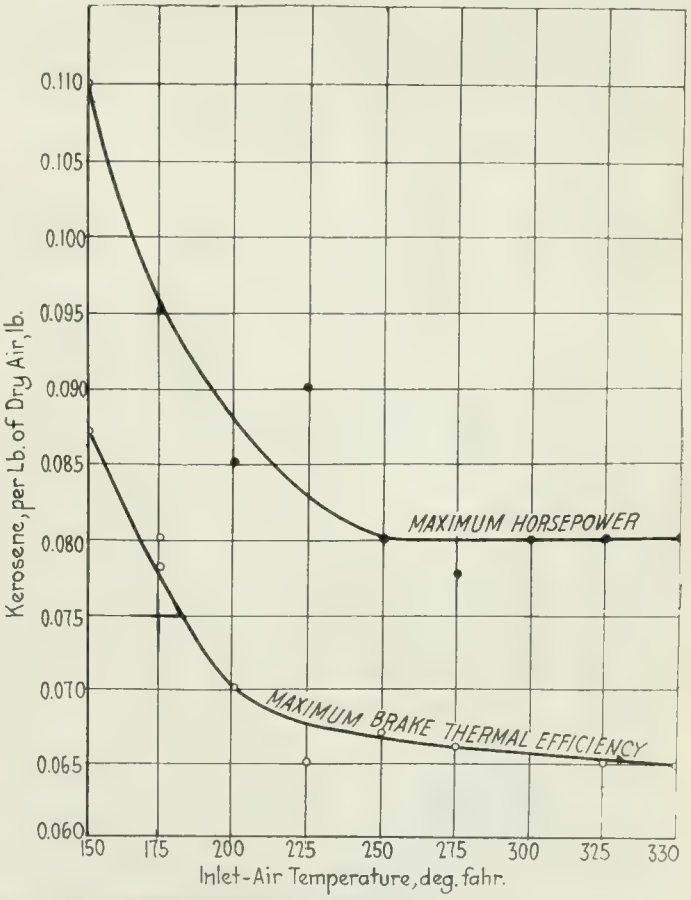


FIG. 19—THE MIXTURE-RATIOS NECESSARY FOR THE MAXIMUM POWER AND EFFICIENCY DEVELOPMENT USING 41.5 BAUME KEROSENE

perature of 250 deg. fahr., as shown in Fig. 18. This being the case, an increase in the dryness of the mixture would not materially aid in the distribution. Below this critical point, the mixture limit for regular operation increases rapidly in richness.

The point in question is shown graphically in Fig. 18, illustrating the richness of mixture necessary to maintain high power and high efficiency. Under the half-load and lower-temperature condition, there evidently is not enough heat absorbed from the air and within the combustion-chamber to allow a sufficiently rapid vaporization for quick combustion. A small change in the heat-content of the air causes a large change in the completeness of combustion. The cooling-loss curves in Fig. 15 present very nicely the low loss occurring at low tem-

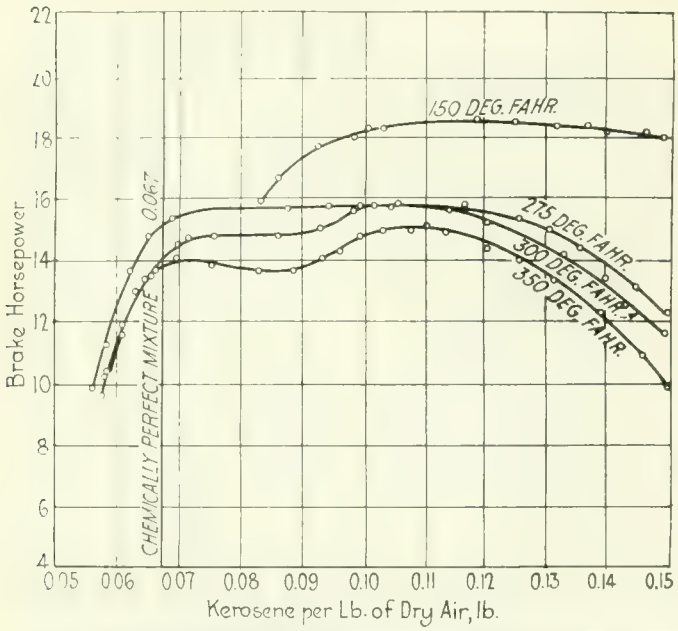


FIG. 20—THE EFFECT OF THE TEMPERATURE ON THE RELATIVE INTENSITY OF DETONATION FROM A POWER STANDPOINT

peratures. A large portion of the fuel is not burned in the cylinder but in the exhaust-manifold; even then it is not burned completely.

Evidently, as shown in Fig. 19, the critical temperature with respect to the mixture-ratio is again 250 deg. fahr. This is the point at which the fuel does not require a leaner ratio for developing the maximum power and also approximates the same point for the maximum thermal-efficiency. Hence, from the values of the thermal efficiency, the cooling loss, the lean limit of inflammability and the mixture-ratio results, the critical temperature for good performance is 250 deg. fahr. With this heavy fuel, the temperature for satisfactory operation is more definitely located than for the gasoline previously mentioned. For practical performance, the temperatures should not go higher, even though more trouble exists from the oil dilution; but, if a method is employed whereby the oil dilution is minimized, then lower temperatures should be utilized. This intake-air temperature of 250 deg. fahr., corresponding to a mixture temperature of about 205 deg. fahr. on the wet bulb, no doubt can be decreased by exceptionally good hot-spot design if the hot-spot allows good distribution.

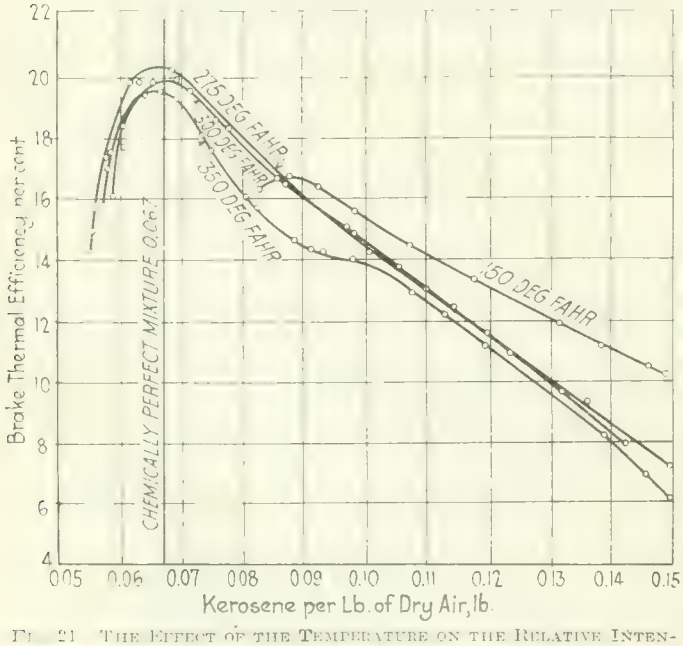

275 DEG. FAHR.
300 DEG. FAHR.
350 DEG. FAHR.
150 DEG. FAHR.
CHEMICALLY PERFECT MIXTURE 0.067
Brake Thermal Efficiency, per cent
Kerosene per Lb. of Dry Air, lb.

FIG. 21—THE EFFECT OF THE TEMPERATURE ON THE RELATIVE INTENSITY OF DETONATION FROM THE STANDPOINT OF EFFICIENCY

DETONATION

Detonation is a factor entering into these tests that has not been mentioned. Some authorities have made the statement that temperature does not affect the intensity of detonation appreciably. A few graphs are enlightening as to the extent of this effect with respect to the temperature. The tests reported previously were run at half-load with a compression-ratio at open-throttle of 4.3 to 1. Detonation was present at 275 deg. fahr., but not of an intensity to affect the power, as shown in Fig. 20, or the thermal efficiency, as is brought out in Fig. 21. An increase of 25 deg. fahr. gave the result shown on the 300-deg. fahr. curves. There is a loss of at least 1 b. hp., as well as a slight decrease in the thermal efficiency. The effect of intense detonation is noted on the 350-deg. fahr. curves by a loss of 11.0 per cent in power and 1.5 per cent in thermal efficiency; and the mixture strength can be varied widely before this effect is entirely eliminated. When the detonation is severe enough to be audible, the mixture range with respect to the inlet-air temperature shown in Fig. 22 is interesting. The lean limit is the more regular, but is only an approximation because the listening method was used. At 150 deg. fahr., no detonation could be detected; but it was present at 175 deg. fahr. At 225 deg. fahr., detonation existed at about as lean a ratio as at the higher temperatures; but it was of less intensity.

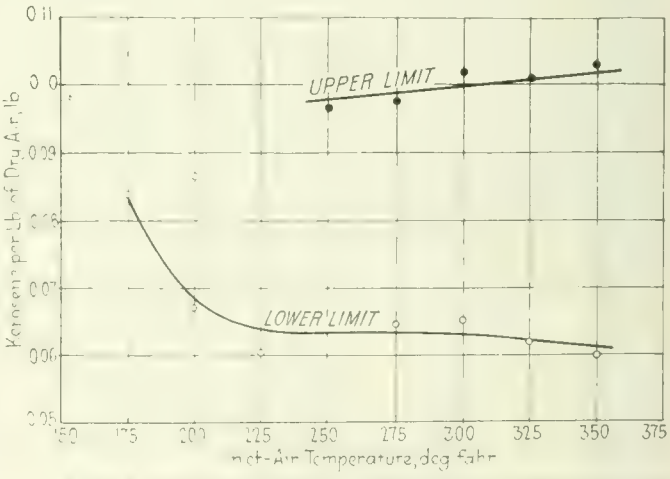


FIG. 22—THE LIMITS OF AUDIBLE DETONATION AS AFFECTED BY THE INTAKE TEMPERATURE

The effect of temperature and detonation on the cooling loss and the exhaust-gas temperatures, illustrated in Figs. 23 and 24, shows that the cooling loss is increased and the exhaust temperature is decreased under severe detonation. Evidently, the combustion is more complete before the exhaust occurs, yet the power and the efficiency are decreased on account of the excessive detonation pressures which result in an increased cooling loss.

EFFECT OF THE LOAD

Another series of investigations was designed to show the effect of the load on the mixture requirements. The tests were made on the same engine and at the same speed as in the previous investigation, using the lowest air-temperature to give good performance. The com-

pression was lowered to 85 lb. per sq. in. absolute, which reduced the intensity of the detonation at the higher loads. At full loads, the detonation remained excessive and diethyl selenide was used to suppress it. A register of the inlet-air and the mixture temperatures is found in Fig. 25. Since the mixture was not entirely dry, wet-bulb temperature-readings are given; moreover, the change with the increased load shows a decrease in the mixture temperature.

Results reported in terms of brake horsepower are perfectly correct for application to some few engines; but,

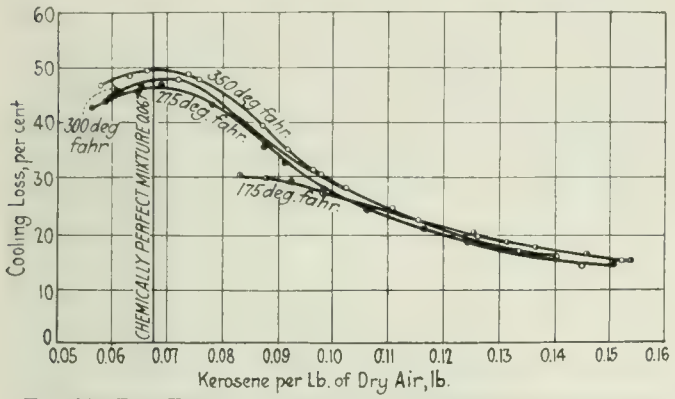


FIG. 23—THE EFFECT OF THE INLET-AIR TEMPERATURE ON THE COOLING LOSS

as very few powerplants consume the same percentage of indicated horsepower as frictional loss, the results must be reported in terms of indicated horsepower to be universally applicable. In these investigations, orifices were used for throttling and the friction was determined, under as near the operating conditions as possible, by the use of the dynamometer as a motor. The friction con-

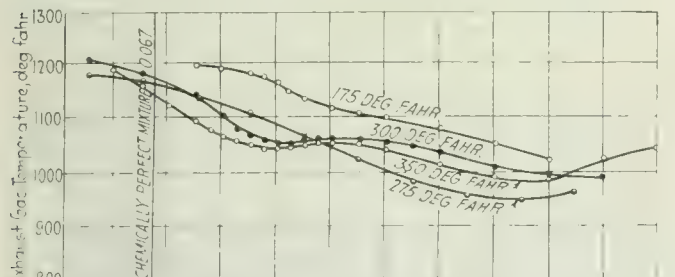

Exhaust Gas Temperature, deg fahr.
Kerosene per Lb of Dry Air, lb
175 DEG. FAHR.
300 DEG FAHR.
350 DEG FAHR.
275 DEG FAHR.
CHEMICALLY PERFECT MIXTURE 0.067

FIG. 24—THE EFFECT OF THE INLET-AIR TEMPERATURE ON THE TEMPERATURE OF THE EXHAUST GAS

sumed or the change of the pumping loss was found with respect to the indicated power and plotted in Fig. 26. The values of the manifold-depressions are included to help illustrate the increase of the friction at the lower loads. This engine requires 56 per cent more power for internal losses at idling than at full load; thus, the throttling increases the rate of fuel-consumption at the low loads.

From the foregoing tests, it is now possible to delineate the mixture requirements of kerosene with respect to the load and in terms of the indicated horsepower. Knowing the requirements for high power and thermal efficiency and the point of zero brake-load, the trend of the mixture-ratios necessary is shown in Fig. 27. Absolute idling, when the maximum power is desired, requires a ratio of 0.0975 lb. of kerosene per lb. of dry air. The poorest ratio required, 0.0800, is not reached until about 48 per cent of the indicated load. At 75-per cent load

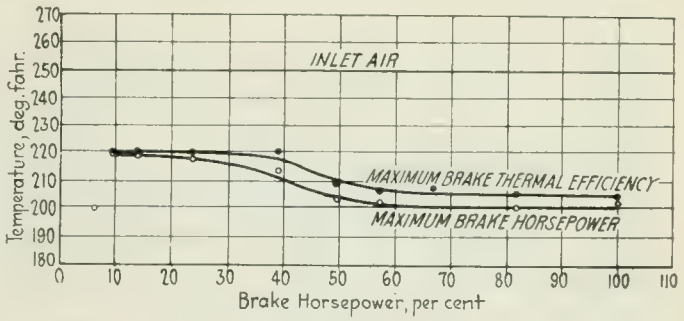


FIG. 25—THE REGISTER OF THE MIXTURE TEMPERATURES AT VARIOUS LOADS

and above it, the mixture enriches slightly, but this is partly due to the slow increase of the power with respect to the increase of the mixture strength. For example, a ratio of 0.0800 develops 33.5 i.hp. and a ratio of 0.0960, 33.9 i. hp.; this is an increase of 1.2 per cent in the power through a range of 19 per cent of the mixture strength. The high-power point is taken as a mean at about 0.0850. An increase of the temperature would

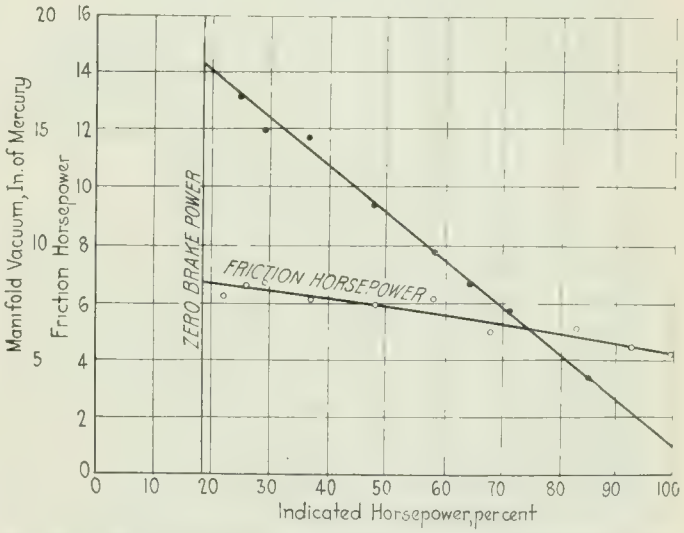


FIG. 26—AN ILLUSTRATION OF THE EFFECT OF THE CHANGE OF LOAD ON THE ENGINE PUMPING LOSS

cause, no doubt, a change of this maximum-power to 0.0800. The theory that the fuel is vaporized in the combustion-chamber by the heat of compression is no doubt true; but, when depending on the compression temperatures, the difficulty is that these temperatures are not of sufficient duration to allow vaporization and a thorough mixing prior to combustion.

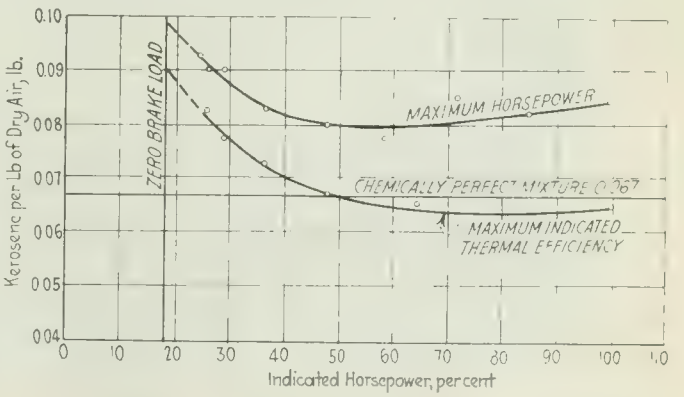

Kerosene per Lb of Dry Air, lb.
ZERO BRAKE LOAD
MAXIMUM HORSEPOWER
CHEMICALLY PERFECT MIXTURE 0.067
MAXIMUM INDICATED THERMAL EFFICIENCY
Indicated Horsepower, per cent

FIG. 27—MIXTURE-RATIO REQUIREMENTS FOR LOAD

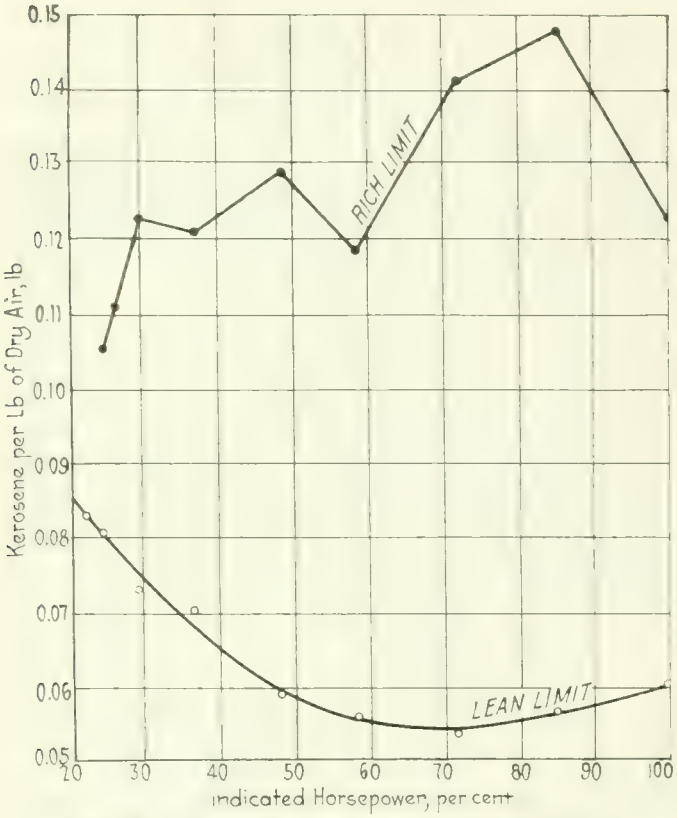


FIG. 28—THE LIMITS OF INFLAMMABILITY FOR LOAD

The thermal efficiency requirements are similar, starting with a ratio of 0.0900 at no load and gradually weakening up to wide-open throttle. The mixture-ratios necessary for the higher loads correspond closely to those necessary for gasoline at the minimum temperature for good operation. The lower loads require somewhat richer ratios for the heavy fuel; that is, at no load, a 9.1-per cent increase over gasoline is necessary.

The change of load also affects the limits of inflammability, the tendency being to widen the limits as the compression pressure or the load is increased. Distribution and mixing at the rich ratios cause an irregular line, as shown in Fig. 28, but the lean limit, which is the more valuable in all cases, is fairly uniform. In no instance does the missing or back-firing occur with mixtures as rich as those required for high efficiency or high power.

FUEL-AIR MIXTURE REQUREMENTS FOR ENGINES

Some authorities prefer to analyze the mixture requirements for engines with respect to the development of a given power. Under throttled conditions, the thermal efficiency will increase with a leaning of the mixture-

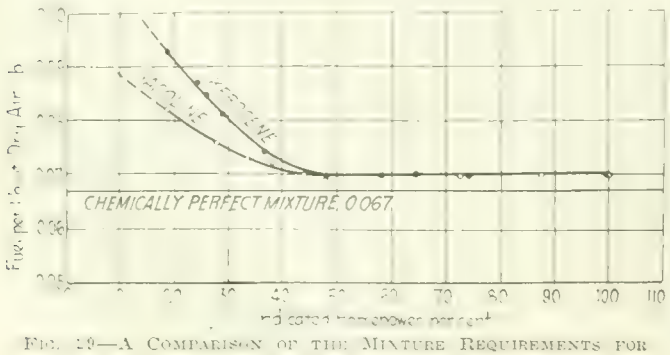


FIG. 29—A COMPARISON OF THE MIXTURE REQUIREMENTS FOR GASOLINE AND KEROSENE WITH RESPECT TO THE LOADS

ratio and will continue to do so until the air-cycle efficiency is approached as a limit. It happens that the limit of inflammability for most engines is 0.0600 or slightly leaner. In other words, to develop a given power as the mixture-strength is weakened beyond the high-power point, the larger throttle-opening necessary causes a higher compression and, hence, a higher thermal-efficiency. Thus, from the standpoint of the engine, where the load is the prime requisite, the analysis under discussion cannot be used. Then, too, at wide-open throttle the analysis must revert from a given power to a constant compression with respect to the mixture-strength.

It has been shown for the two fuels, in Figs. 13 and 27, that it is an impossibility to develop the maximum power, the maximum thermal-efficiency and good performance with the same mixture-strength. This being the case, a mixture-strength must be determined that will deliver good engine performance and a compromise between power and efficiency; and this is especially true at points above 48 per cent of the indicated horsepower. Kerosene, with proper preparation, will operate with mixture-ratios as illustrated in Fig. 29. Below 48 per cent of the indicated load, the ratios required grow somewhat rich. At 18.3 per cent of the indicated or zero brake-load, the mixture is 0.0925 lb. of fuel per lb. of dry air or slightly richer than the maximum thermal-efficiency ratio. The ratio for 56.5-deg. Baumé gasoline

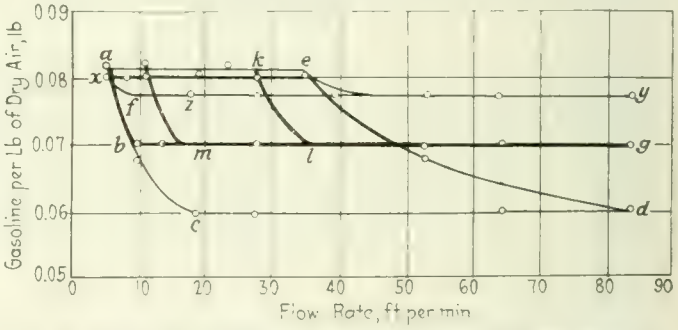


FIG. 30—MIXTURE REQUIREMENTS FOR POWER AND EFFICIENCY AT VARIOUS SPEEDS AND LOADS WITH 56.5 BAUME GASOLINE

at zero brake-load is 0.0825, and it decreases to 0.0700 lb. of fuel per lb. of dry air at 42 per cent of the indicated load. Both fuels will develop nearly the maximum efficiency until a mixture-strengeh of 0.0700 is reached. As the load is increased, it will be noted that 95 per cent of the power limits the mixture to 0.0700 for the two fuels; and this is the power sacrifice necessary to secure a higher efficiency and yet not impair the engine operation.

Knowing the effect of the speed and the load on the engine mixture requirements and operating under satisfactory temperature conditions, a graph can be drawn with respect to flow-rate that is of special interest to carburetion engineers. In Fig. 30, the mixture-ratios for gasoline are plotted against flow-rate, which can be expressed in either weight or volume per unit of time. The limits for maximum efficiency at a low speed are shown by the curve *a b c* in Fig. 30, and at some higher speed by the curve *e d*. The limit for power at the low speed is the curve *x f z*, and at the higher the curve *e y*. From the data in Fig. 29, the good-performance mixture follows very closely the maximum-efficiency ratios until about 42 per cent of the indicated load is reached; it then maintains a constant mixture; hence we have the ratios *a b m*. Similarly, for a higher speed, the curve *e g* represents the metering characteristics. Separating the metering characteristics from the power and efficiency graph, Fig. 31 presents the ratios that a carbureter must deliver to allow the best engine performance. The only manner in which

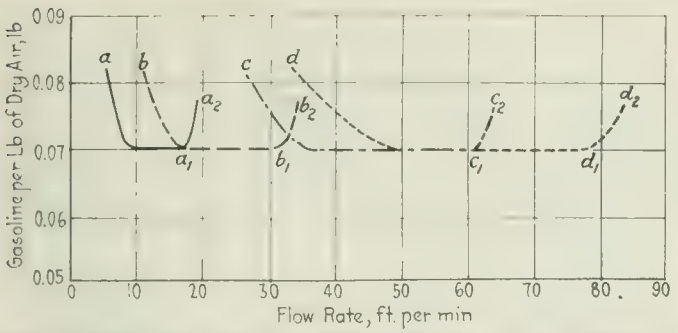


FIG. 31—THE ENGINE MIXTURE REQUIREMENTS FOR GOOD PERFORMANCE USING 56.5 BAUME GASOLINE AS FUEL

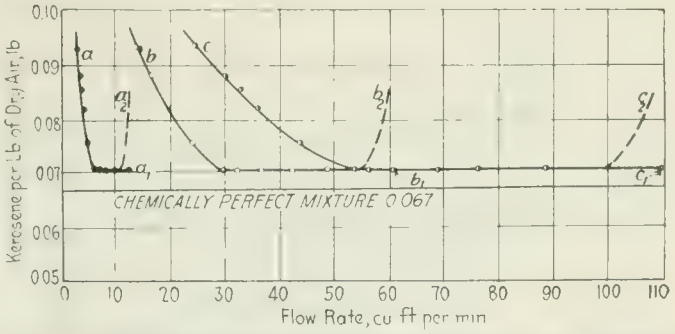


FIG. 32—THE ENGINE MIXTURE REQUIREMENTS FOR GOOD PERFORMANCE USING 41.5 BAUME KEROSENE AS FUEL

the characteristics are changed is by causing the mixture to return to the maximum power-value, a 5-per cent power change, at open-throttle positions, as this is the main interest at this condition. The curve $a\ a_1\ a_2$ illustrates the requirements at low speed; any one of the other curves, such as $d\ d_1\ d_2$, shows the requirements at the higher speeds.

The metering characteristics for kerosene are derived similarly to those for gasoline, but call for a larger variation of the ratio with respect to the load, as shown in Fig. 32. Absolute no-load, or zero brake-load, requires 0.0975 lb. of fuel per lb. of dry air; this decreases to 0.0700 at 48-per cent indicated load and just before the open-throttle and more fuel is demanded until a mixture of 0.0850 is reached at the open position. The metering characteristics outlined for kerosene represent the results from only one engine. The gasoline data are more complete, as several engines of different types have proved the same thing. Even though the data from kerosene are meager with respect to other engines, the results will blaze the way and provide the limit to which the metering characteristics for engine operation will tend to go with fuels of decreased volatility.

CARBURETER REQUIREMENTS

When economy is the chief interest in operating throttling internal-combustion engines, the ideal toward which we must strive in practice is somewhat different from that previously explained. The requirements mentioned were from the standpoint of the engine, and they do satisfy its power and efficiency requirements. When the engine is placed in a car and the car requirements for satisfactory performance with maximum economy are outlined, the carbureter is changed of necessity. The first requisite is easy starting; the second, good idling; the third, instantaneous acceleration; and the fourth, economical constant-speed and load operation.

Proper temperatures must be maintained at all costs, as distribution and combustion are affected greatly by the temperature. Proper atomization is not of necessity a requirement; but it is essential in using present methods of carburetion and assists greatly in starting. The idling must be at mixture-ratios developing high power and comparable to the engine requirements. All points of constant-speed or load operation above idling and under throttled conditions must use a mixture-ratio that is just rich enough for regular inflammability. As the ratio is weakened, the efficiency increases with the air cycle as a limit; so, the limits of inflammability are those of practical operation. For constant speed, the throttle position does not matter and the analysis with respect to a given power applies. The difficulty arises when a change of the speed and the load is necessary and, unless the ratios are returned to the high-power strength, poor operation will result. The requirement for acceleration is then to change the mixture-strength to 0.0775 for gasoline, or 0.0850 lb. of fuel per lb. of dry air for kerosene instantaneously and temporarily; then to re-

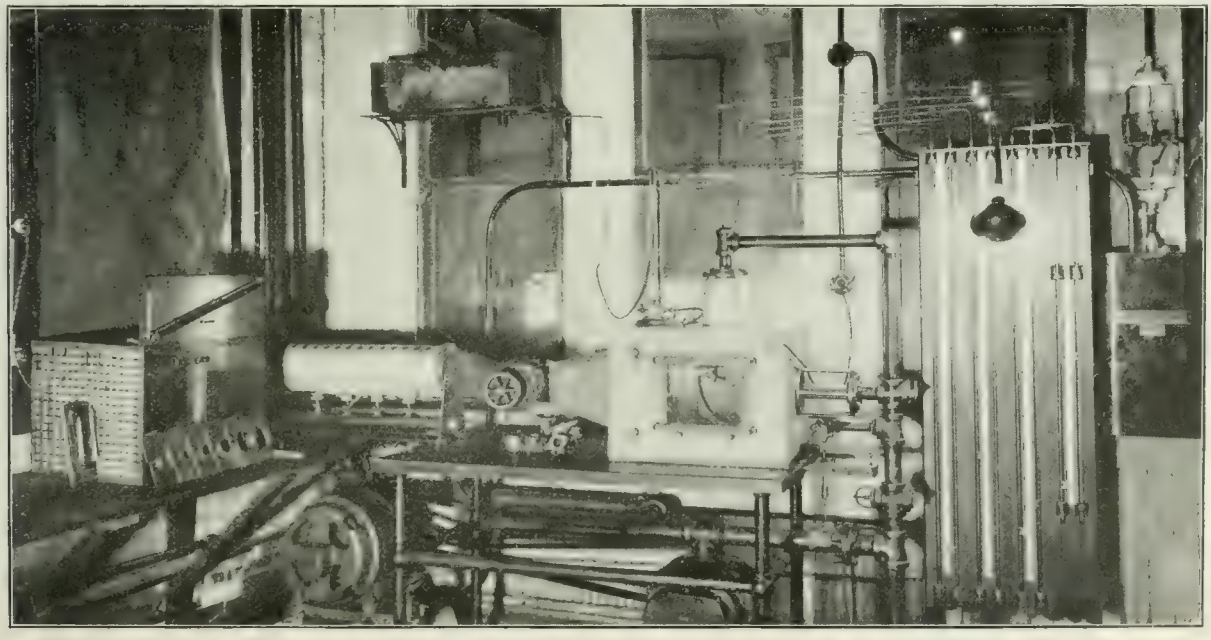


FIG. 33—THE PLANT FOR TESTING COMPLETE OR COMPONENT PARTS OF CARBURETERS

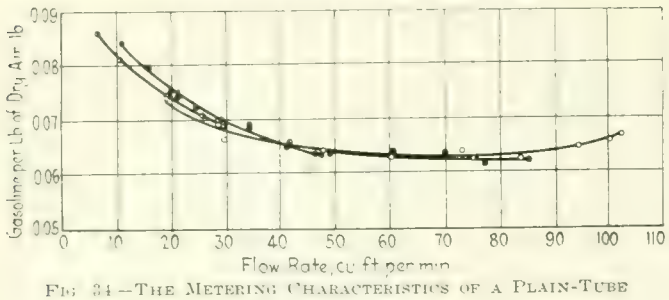


FIG. 34.—THE METERING CHARACTERISTICS OF A PLAIN-TUBE CARBURETER

turn to the original lean-ratio at constant conditions. When open-throttle is attained, maximum power is the main consideration; this again requires that the mixture ratio be enriched to 0.0775 for gasoline and 0.0850 for kerosene and permanently held there for the maximum load. It will be noted from this discussion that the car requirements for constant speed differ from

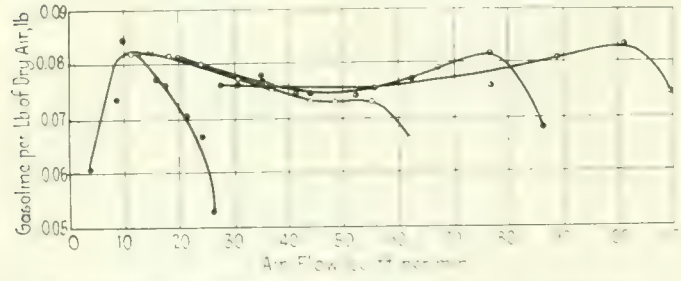


FIG. 35.—THE METERING CHARACTERISTICS OF A COMMERCIAL CARBURETER

those of the engine only in that the mixtures are leaner between idling and full throttle.

COMMERCIAL METERING CHARACTERISTICS

How nearly the metering characteristics of various commercial carbureters fulfill the ideal, can be noted from the curves that present the results of investigations made with the new carbureter-testing plant, at the Purdue University Engineering Experiment Station, Fig. 33, which is similar in some respects to that at the Bureau of Standards.

Two methods were employed in these tests. Instead of making the usual mixture-ratio versus flow-rate curve from idling to the maximum capacity, the flow-rate was broken into at least four sections representing the same number of engine speeds; then, the carbureter throttle was operated only for the change of the load. In this manner many irregularities of metering can be shown that the conventional method or level-road operation will not discovered. Since the ideal carbureter requirements are known, this method compels the carbureter to recognize more than air-flow. The carbureter, the metering of which is shown in Fig. 34, has the flow-rate divided into four different speeds to present the change-of-load data. The metering in this case is not affected materially by the engine load, but almost entirely by the air-flow, as the four curves nearly coincide at idling. At wide-open throttle, the mixture-strength is not increased to the high-power point. This metering, while allowing operation, does not conform to economical and satisfac-

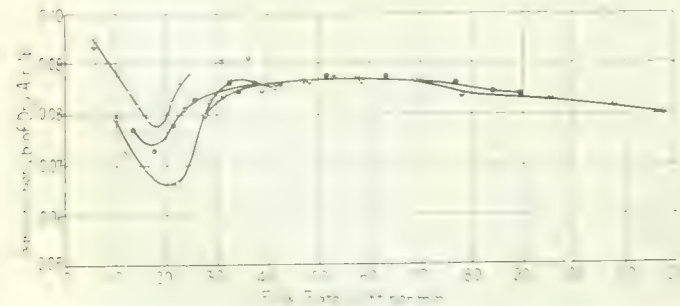


FIG. 36.—THE METERING CHARACTERISTICS OF ANOTHER COMMERCIAL CARBURETER

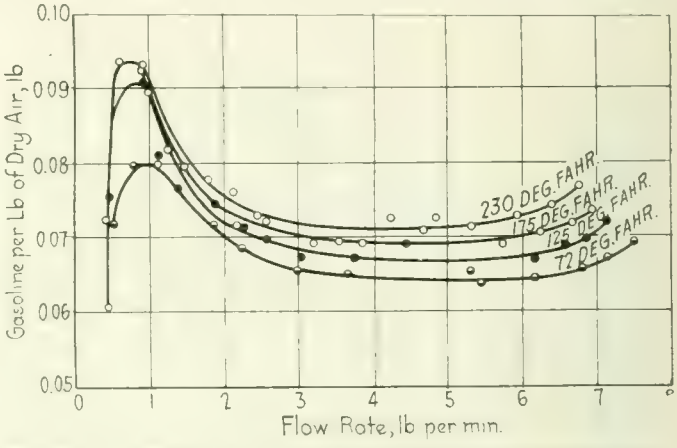


FIG. 37.—THE EFFECT OF THE TEMPERATURE ON THE METERING OF A COMMERCIAL CARBURETER

tory car-performance. In the case of the carbureter presented in Fig. 35, the metering is entirely different from the ideal. At the two medium speeds the idling is good; but it is poor at the low speed. At wide-open throttle, the mixture leans rather than enriches and, at the low speed, it is so lean that the engine probably would not operate. At throttled conditions the leaning is not sufficient, thereby wasting fuel. The results of a third type of carbureter shown in Fig. 36 do not more nearly approach the ideal. In the discussion of this third type,

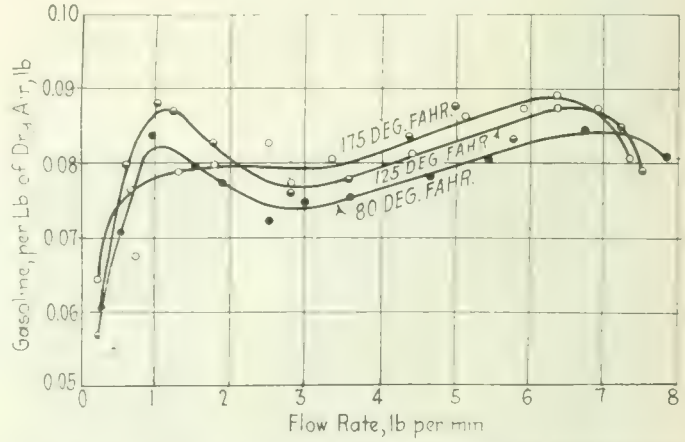


FIG. 38.—THE EFFECT OF THE TEMPERATURE ON THE METERING OF ANOTHER COMMERCIAL CARBURETER

it is assumed that the adjustment will be transferred nearer to the ideal mixture-strength. The idling at the extreme low speeds is good; but, at higher speeds, it is uncertain on account of lean ratios. At other throttled loads, the ratios are strengthened instead of weakened, and in all the higher speeds the maximum power would not be developed owing to the weakened ratios. The ratios between 15 and 30 cu. ft. per min. are erratic. Check-tests made were perfectly good at the higher flow-rates, but any mixture-ratio might be expected between the limits mentioned. Judging from the few examples

shown at constant speeds and loads, the metering is by no means ideal.

The change of the temperature, of both the fuel and the air, affects the metering. The influence of the fuel temperature can be controlled by the design of nozzles, jets and passageways, but the effect of the air-temperature requires a more complicated design. The carbureter in the two cases shown, in Figs. 37 and 38, illustrates the change of mixture-ratio at the same flow-rates for a few temperatures. In this instance the test approximates the metering characteristics delivered when operating on a level road; that is, change of the speed and the load combined. The carbureter, the characteristics of which are illustrated in Fig. 37, enriches about 8 per cent per 100-deg. Fahr. increase. The other device at a slightly richer mixture shows 7 per cent per 100-deg. Fahr. change. The temperatures studied are from 75 to 225 deg. Fahr.; they cover the ordinary range with the exception of the low temperatures after starting. In designing thermostatic controls, other temperatures must be considered in addition to those of the air and the fuel.

The question of acceleration is of prime importance at any time. If an instrument is designed to fulfill the carbureter requirements, the acceleration must be very carefully studied and the mixture-ratios maintained unfailingly accurate. Too little compensation will meet with failure, and too much will produce a waste of fuel.

One other point worthy of note is the frictional loss across the carbureter. Probably the worst offender in cutting down the engine power, and hence the efficiency, is the plain-tube and allied types. However, there are some air-valve devices that show a high frictional-loss. This is illustrated in a comparison of two plain-tube types and an air-valve type, all of 1¼-in. size, shown in Fig. 39. The first plain-tube carbureter has a very high loss before the metering characteristics break-down; the air-valve type is very much lower but, even so, the loss is too high for this type and the capacity is rather low with respect to metering. The other plain-tube carbureter is lower than the air-valve type, even though it is a plain tube, and the metering characteristics are just beginning to show an enrichment toward the break-down point. The frictional loss is critical just above 120 cu. ft. per min., which would limit the capacity.

The causes of the high fuel-waste due directly to the carbureter are: (*a*) improper mixture-ratios; (*b*) poor acceleration, (*c*) omission of temperature control, and (*d*) high fluid frictional-loss.

With cars operating at ordinary speeds, the percentage of engine load is small and requires a high manifold-vacuum; this results in a large engine pumping-loss. The leaner mixtures allow a higher compression for the same power development, which reduces this large pumping-loss. If little or no provision is made for acceleration, the mixture must be made so rich that no real economy at constant-speed operation can be obtained. In a practical device that fulfills the necessary requirements, the acceleration feature is so important that no operation could be effected without it; in fact, the metering device and other features might well be built around it.

The frictional loss across the carbureter is much higher

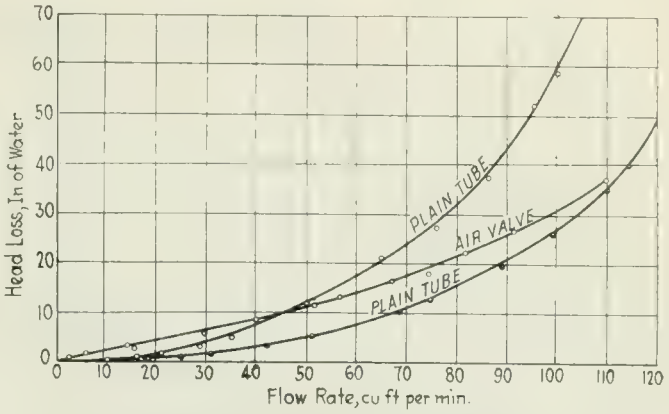


FIG. 39—THE FRICTIONAL LOSS THROUGH CARBURETER BODIES SHOWING THE RELATIVE POWER LOSSES

than through the manifold, and this makes it essential to cut this loss to a minimum. Perhaps a little standardization of the flow-rate capacities and head losses in connection with the carbureter flanges would aid materially in eliminating fuel waste.

The question of temperature and the resulting effect on the metering characteristics is one that needs more research for its absolute determination. Each individual device has its own peculiarities, and some simple automatic control should compensate for summer and winter operation; if preheated air is used, there is all the more necessity for a temperature compensation. Also, engine temperatures on starting and for warming must be included. It is practically impossible to expect 10,500,000 drivers to make their own dash-adjustments for this temperature correction, and the fuel loss is too great to allow inattention.

CONCLUSION

On retrospection, we note the short period of time for the marvelous development of the throttling internal-combustion engine, and, on account of its flexibility, we cannot do otherwise than consider it the automotive engine of the future. In so doing we must realize that now is the time for increasing the expansion-ratios to allow high engine-efficiency, and good carburetion must be effected whereby that high engine-efficiency can be realized to give the maximum return in ton-mileage per gallon. Even though the fuel does not decrease in volatility to the extent previously mentioned, from the standpoint of the motoring public and from an economic viewpoint, carburetion, as applied to the present-day equipment, is far behind the other component parts of the engine. More effort is being expended each year on carburetion development, and the day is at hand when the United States must efficiently utilize more than 75 per cent of its annual consumption of gasoline.

We wish to acknowledge our appreciation to J. W. Geiger, H. A. Huebotter and Opie Chenoweth of the Purdue University Engineering Experiment Station for their assistance in conducting the tests and computing the results of the various investigations presented in this paper.

HIGHWAY ECONOMICS

A SURVEY of highway development as it is today shows that we are appropriating annually sums aggregating more than $1,000,000,000 for city and rural highway construction and maintenance. A further survey of our needs shows that this program must be continued for 10 years or more if we are to arrive at a connected system of highways that will render the greatest possible service to the public.

If we were dealing with this question in the untroubled days before the world war, the matter of finance would be a relatively easy one and we would not be so much concerned with ways and means. But it is necessary to remember that today the Nation is carrying a heavy tax-budget and, what is more important, that the State and county levies are at higher levels than they have been in the past.

We must weigh well all of the elements entering into any appropriation for any purpose and only those must be made that we know will surely return a direct profit to the public. Further, we must seek to allocate definitely those profits so that the burden will be borne in as large a measure as possible by those who are the beneficiaries.

Broadly speaking, we all agree that those who are alive today and those who come after them down to the children of the third and fourth generations, will benefit from highway construction, provided that, once constructed, the highway is maintained.

The cost of highway construction should be divided accordingly, which, of course, at once implies long-term highway bond issues. Engineers tell us that from 40 to 50 per cent of the cost of construction of a highway is a permanent investment, assuming that the highway has been properly located. The right of way, the grade, the drainage, bridges, shoulders and engineering costs need be paid only once. It is the surface that wears. Engineering records show that here the loss is less than is popularly supposed since in the rebuilding of a surface it is possible to salvage much of the material and use it for a base for new surfacing.

Considering the improvement of the main State systems, which will average about 7 per cent of the total mileage of this Country, this system, when completed, will place all of us on main roads, or but a few miles away; and through the feeder lines we will be enabled to reach the great highway and deliver our commodities to market.

We are proposing that this generation shall undertake to build these roads, charge the cost to capital account, pay for them by long-term bonds, use them and pass them on to the next generation in as good or better condition than we built them. We propose that each generation shall pay a fair rental charge for the use of these roads in the sum of amortization charges and interest, plus maintenance. Interest on bonds and amortization should be paid for from general taxation. Maintenance costs should be charged against traffic. Maintenance should include all charges up to and including reconstruction, save extensions or added replacement costs where an inferior is replaced by a superior type of surface. Only that type of road should be constructed which is adequate for the needs of present and future traffic, as determined by careful surveys of both traffic and economic possibilities.—A. J. Brosseau.

FARM AND URBAN INDUSTRIES

IF the farm production of the Country be taken as a whole, our agricultural producers are receiving for their work but a trifle more in money than they received before the war and in purchasing power, which is the essential thing, less than 70 per cent of their prewar remuneration. In other words, their productive operations are completely unprofitable and they have every incentive to better their economic condition by abandoning the farms in favor of those industrial and urban occupations that are visibly several times over superior to their own. And insofar as the farm wage-earners, as contrasted with the farm-owners, are concerned, this incentive is rendered more powerful by the fact that the farm-owner cannot afford, with the prices of agricultural products what they now are in both an absolute and a relative sense, to put wage-costs into what they produce; so that in many sections of the Country we have the curious spectacle of a greatly reduced supply of farm labor that is nevertheless redundant even at very low wages. Thus reports from all parts of the Country recently obtained by the Department of Agriculture showed an excess of the supply of farm labor over the demand in respect of 36 per cent of the reporting districts, an even balance of supply and demand for 31 per cent of the reporting districts, and a slight excess of the demand over the supply for only 33 per cent.

The Country is entering upon a vast process of economic readjustment in which its agricultural production will decrease relatively to a sufficient extent to enable the forces of supply and demand to bring the prices of farm products in general into a proper balance with the prices of industrial products. Speaking from the standpoint of economic law, it will be through this process of readjustment, necessarily painful to all concerned, and not through increased credit facilities and the like, that the disadvantages from which the farmers now suffer, and about which they inevitably complain, will in the end be rectified.—A. R. Marsh in *Economic World*.

ABRASIVE QUALITIES OF STEELS

MODERN equipment is designed for high speed and heavy duty. The manufacturers have met this condition by using heat-treated plain carbon and alloy-steels in the moving parts, such as gears and cams. Application of various types and grades of steel has brought forward the fact that any one steel cannot be used indiscriminately but must be studied in relation to the service for which it is intended. An introductory study of the effect of heat-treatment on the abrasive qualities of plain carbon and alloy-steels indicates that the greater the density and hardness are, the greater the abrasive resistance will be; the ordinary tension and Brinell tests are not a reliable index to the abrasive qualities of a material; the carbon-steels tested showed more uniform results than the nickel-chromium steels and less average wear-loss; and an extensive series of additional tests will have to be made before it will be possible to determine with any degree of certainty the combined effect of ductility and hardness on the abrasive properties of materials.—From a paper by A. M. Cox presented at a recent meeting of the Pittsburgh Section of the American Society for Steel Treating.

The Development of the Hannover Sailplane

By Georg H. Madelung[1]

Cleveland Section Paper *Illustrated with* Diagrams

KEY TO FORMULAS AND SYMBOLS

The symbols and formulas given below relate to all of the charts reproduced as well as to the text of the paper, and are grouped in this manner for ready reference by the reader:

A = Area of Wing.
$A_i = \Sigma(A_p K_x)$ = Apparent Parasitic Area
A_c = Circumscribed Area of Torque Tube
A_p = Parasitic Area
a = Distance of Beam Axis behind Leading Edge
b = Height of Beam Axis above Chord
c = Mean Chord
$c_i = \Sigma(K_y c) = L/sq$ = Apparent Chord
$D = D_p + D_i + D_s$ = Total Drag
D_i = Induced Drag
D_p = Parasitic Drag
D_s = Section Drag
FS = Factor of Safety
$f = D_s/L$ = Section Drag Divided by Lift Ratio
γ = Gliding Angle; $\tan \gamma = D/L$; $\sin \gamma = w/v$
k, k_1 = Factors Used in the Theory of Induced Drag
$K_m = M/qAc$ = Coefficient of the Moment about the Leading Edge
K_{m_1} = Coefficient of the Moment about the Beam Axis
$K_n = K_y \cos \gamma + K_x \sin \gamma$ = Coefficient of Normal Force
$K_T = K_x \cos \gamma - K_y \sin \gamma$ = Coefficient of Tangential Force
K_x = Drag Coefficient
$K_{xs} = D_s/Aq$ = Section-Drag Coefficient
K_y = Lift Divided by the Area of Dynamic Pressure = Lift Coefficient
L = Lift
M_t = Torque Moment about the Beam Axis
$q = \rho(v^2/2)$ = Dynamic Pressure
ρ = Density of Air
s = Span
t = Shear-Strength
th = Wall Thickness
v = Forward Speed
W = Weight
w = Sinking Speed = Rate of Descent

AFTER distinguishing between airplane-racer and sailplane problems, the author discusses the soaring problem briefly and concludes that the outstanding requirement is a minimum rate of descent, since this is the factor that determines the merits of the sailplane. He mentions some features of the early gliders, and then gives an analysis of the rate of descent, subdividing the drag into the three factors of parasitic, induced and section drag, and analyzing each separately with the aid of diagrams.

The span, the wing section and the best chord receive similar treatment. Reasons are given why it was not deemed advisable to build a biplane, the total amount of the rate of descent is determined and the total gliding-angle is subdivided into its proper parts of parasitic, induced and section drag. After stating why external bracing was not used, the form and arrangement of the sailplane body are described and tests of a model are commented upon, together with a brief discussion of the results of some static tests on a piece of the beam. A detailed analysis of torque and the torque moment is included. The radical departures from the conventional practice that were incorporated in this sailplane are stated to be the football wheels, a body of unusual form and arrangement, the large span, the single beam and the torque-carrying plywood-cover.

IT has been stated, in regard to the difference between racer and sailplane problems, that the racers which competed for the Pultizer trophy at Detroit are: "The opposite extreme, in tremendous power applied to the airplane, from the gliders with no power that have been flown recently in Germany." That statement is very true, and it remains true when it is applied to the construction of the wing or any other part. In the case of the racer, large forces are concentrated upon a compact structure; in the case of the glider, small forces only are concentrated, but they are carried by a spacious structure. The victorious Curtiss Army racer had 1950 lb. of gross weight and a 19-ft. span; the Hannover sailplane has only 430 lb. of gross weight, but it has a 41.3-ft. span. Therefore, the structural problems are different.

The same extreme difference appears also in the aerodynamic problems. The victorious Curtiss racer performed at a racing speed that was more than three times its landing speed. It had, therefore, to show its merits at an extremely low lift-coefficient, which is only about 10 per cent of the coefficient of its maximum lift. Two opposite cases had to be considered:

(1) Low angle of incidence; very little lift required; and all effort concentrated to the reduction of drag
(2) High angle of incidence; lift as large as possible; and drag of no importance

It is clear that two requirements that are so different must handicap each other. No such handicap exists in the case of the glider. Its maximum performance is only 10 to 20 per cent more than the landing speed. The case is that of a high angle of incidence, a high lift and a drag that is as low as possible. The characteristic difference between the problems of the racer and those

[1] M.S.A.E.—Project engineer, Glenn L. Martin Co., Cleveland.

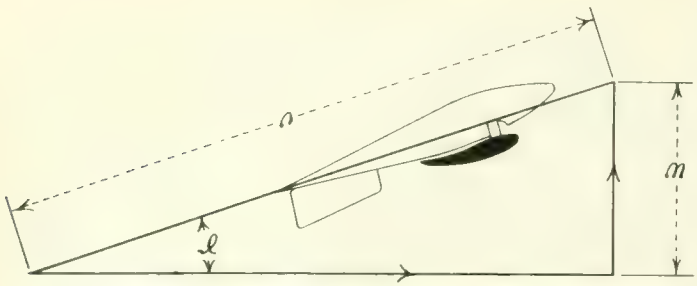


FIG. 1—DIAGRAM ILLUSTRATING THE RELATION EXISTING BETWEEN THE SINKING SPEED OF A SAILPLANE AND THE RATE OF TRAVEL THROUGH THE AIR

of the glider must be recognized clearly. The knowledge of the problem shows the way to its solution.

In the last Rhoen meetings, the highest rewards were offered to those sailplanes that would remain the longest time aloft and rise above the starting point. It seemed to be easy to rise above the starting point if only the up-current were strong enough. However, this result had never been realized. Flights of several minutes' duration had been made but with a considerable loss of altitude. None of the gliders had been able to continue to soar at the same altitude for even 1 min., and Orville Wright's record remained unbroken.

In April, 1921, when I was asked by Professor Proell to design a sailplane for the Hannover Institute of Technology, I was possessed with two ideas. One was that of a biplane with a very thin wing of low minimum drag. The other was that of a monoplane of high wing-loading, having slotted wings. The slots were supposed to be open for the landing condition and to bring a high lift, with a very bad drag, of course; for higher speed, the slots were to be closed. I discarded both ideas, although they would have been useful if a large ratio of speeds had been required, as in the case of the racer. In our case, however, the outstanding requirement is *a minimum rate of descent.*

The rate of descent is the factor that determines the merits of the sailplane. To soar means to sink more slowly than the wind rises. A good pilot is able to acquire power from windgusts. This may be 1 per cent of the total required power, 10 per cent or perhaps more. We know so little about the turbulence of wind that I do not know what the percentage of power acquired in this way would be. But we know the sinking speed of the airplane, and we know how to influence it.

In the early gliders, not much had been done to reduce the rate of descent. The effort of the designer was to make the glider as light as possible, and to reduce the landing speed. The extreme of this tendency was exemplified in the Pelzner glider, a biplane having an area of about 180 sq. ft. and carrying 50 lb. of dead-load. Such a very small amount of dead-load is desirable in the case of a glider that is without landing-gear, where the pilot starts with and lands on his own feet. To fly such a glider is a wonderful physical performance; maybe it is even a better sport than soaring in a sailplane. But the flying performance of the Pelzner glider was exceedingly poor. In 1920, the Klemperer glider was developed by the Aachen Institute of Technology. It was built like a real airplane and followed the sound principles of conventional aircraft engineering. Piloted by Klemperer, it won all the first prizes at the 1920 meeting. However, the rate of descent had not been given first consideration in its design; it made fine flights, but it did not succeed in soaring.

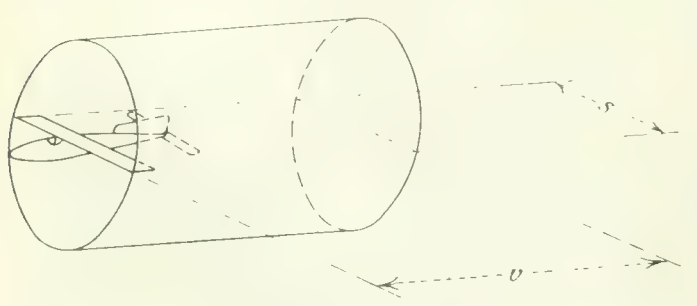


FIG. 2—HOW THE AIR PASSING ABOVE AND BELOW THE WING OF A SAILPLANE PRODUCES LIFT

ANALYSIS OF THE RATE OF DESCENT

Let us determine by what means a low rate of descent can be obtained. With reference to Fig. 1, the sinking speed is the vertical component of the travel through the air and $w = v \sin \gamma$. So long as the gliding angle γ is small, it can be approximated by $w = v \tan \gamma = v\,(D/L)$. It appears that a good gliding-angle or a low drag, and also a low speed, contribute to our purpose. In considering how these values are determined, it is necessary to divide the drag into (*a*) parsitic drag, (*b*) induced drag and (*c*) section drag.

The conception of the parasitic drag is sufficiently well known. It is produced by the non-lifting parts such as the body, the landing-gear, the tail-skid, the tail surfaces and the like. We have

$$D_p = \Sigma(A_p K_r) q$$

In abbreviated form,

$$D_p = A_p q$$

The induced drag, that part of the drag of a wing which is induced by the lift, was introduced by Professor Prandtl of Goettingen and his co-workers. The idea can be explained by the following approximation. In Fig. 2, a certain mass of air passes above and below the wing, and it is used to produce lift. Therefore, $Q = \rho K s^2 v$. To produce the lift, it must receive the downward movement behind the wing, and $W_1 = L/Q = L/\rho K s^2 v$. Under the wing, the current has already reached part of this downward movement. An analogy is that the air yields under the wing like loose sand under one's feet. The larger the shoes one wears and the faster one walks, the less the sand will yield. It is tiring to walk through loose sand. With each step, one must climb from the hole the other foot has made. This same effect applies also to the wing. It produces its own down-current and, to maintain constant altitude, it must rise constantly in its own down-current. This rising produces the induced drag and

$$D_i = L\,(w/v) = L^2/k_1 \rho s^2 v^2$$

The value of k_1 can be determined by experiment. Prandtl determined it by the methods of classic hydrodynamics and checked the result by experiments. He found that $k_1 = 0.5\,\pi$ for the monoplane; $k_1 = 0.6\,\pi$ for the biplane, with a gap-span ratio of about 1 to 10; and $k_1 = 0.65\,\pi$ for the biplane, with a gap-span ratio of about 1 to 6. This means that a biplane can utilize a little more air to produce lift than a monoplane having the same span, and, the greater the gap is, the more air it can use. Therefore, for the monoplane, $D_i = L^2/\pi\, s^2 q$, and, for the biplane with a gap-span ratio of 1 to 10, $D_i = L^2/\,1.2\,\pi\, s^2 q$.

The conception of section drag is assisted by reference to Fig. 3. The induced drag would be the drag of the ideal wing, with ideal distribution of lift and no skin friction. We find, however, from experiments, that an

additional drag exists, due to the wing imperfections. An idea of the origin of this trouble can be obtained by looking from the deck of a steamer down to its waterline. The skin of a ship is covered by a sheet of heavily turbulent water, 2 or 3 in. thick on the sides and dissolving at the rear into a deadwater, a broad band of vortexes. The same effect occurs on wings, and the drag that it produces is called section drag; so,

$$D_s = K_{xs} A q$$

or, in another form,

$$D_s = fL$$

The second form of the section-drag equation is the more useful for our purpose. The factor f can be considered as a friction coefficient, a measure of the imperfectness of a section. The factor f is, of course, not a constant; it is different for every angle of attack. In a racer, a wide range of angles must show a low section-drag; in our case, we have no such handicap and consider only the minimum value of f. In many sections, we find $f_{min} = 1/40$; frequently, $f_{min} = 1/50$; occasionally, $f_{min} = 1/80$.

Having completed the subdivision of the drag, we can now write the formula for the total drag. It is

$$D = D_p + D_i + D_s$$

or,

$$D = (L^2/\pi s^2 q) + A_1 q + fL$$

But, in this form, the formula is not yet useful to show the influence of the dimensions of the sailplane upon the performance. To show this influence, the dynamic pressure q must be eliminated and be replaced by the lift, L, the apparent chord, c_1, and the span, s.

Since $q = L/sc_1$, we obtain the formula for the gliding angle. For the monoplane, it is

$$\tan\gamma = D/L = A_1/c_1 s + c_1/\pi s + f$$

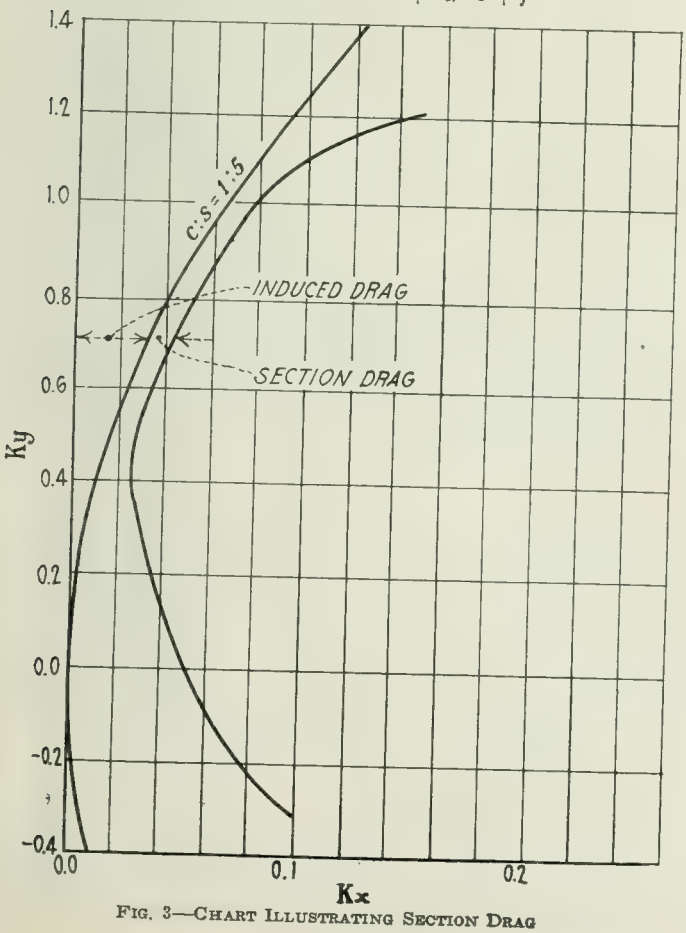


FIG. 3—CHART ILLUSTRATING SECTION DRAG

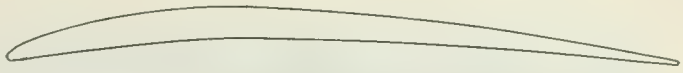


FIG. 4—THE GOETTINGEN WING SECTION NO. 427

For the biplane having a gap-span ratio of 1 to 10, it is

$$\tan\gamma = A_1/c_1 s + c_1/1.2\pi s + f$$

The next step is to express the speed, v, when using the same values. We have, $v = \sqrt{(2L/\rho\, c_1\, s)}$ and, by introducing it into the equation, we obtain the rate of descent

$$wv\tan\gamma = [\sqrt{(2L/\rho)} \times \sqrt{(1/c_1 s)}]\,[(A_1/c_1 s) + (c_1/\pi s) + f]$$

for the monoplane, and we can write a corresponding formula for the biplane. This formula is very useful. It contains no factors other than the well-known density of the air and a few dimensions of the craft such as L, the weight or lift; c_1, the apparent chord; s, the span; A_1, the apparent parasitic area; and f, the "friction" coefficient of the section. These craft dimensions can be estimated or determined easily.

It is remarkable how large a function the span has upon the rate of descent as expressed in the foregoing formula; s is found below the line only. An increase of span must, therefore, reduce the sinking speed. It was for that reason that I insisted on giving the sailplane the largest span that we believed we could handle. The importance of the amount of span has not been fully understood outside, even by experts. For instance, the editor of *Flight* speaks about "the wing span, which is obviously somewhat large," on Aug. 31, 1922, after the record was broken. I even had difficulty to obtain permission to use such a large span as I did use. To quote from my letter of April 30, 1921, I had to explain that

> If we reduce the span, the induced drag will increase. It is $D_i = L^2/\pi s^2 q$. In our case we estimate that the lift, L, is 310 lb.; the span, s, is 41.3 ft.; and the dynamic pressure, q, is 1.28 lb. per sq. ft. If we have to reduce the span to the railroad limit, 29.5 ft., the drag will increase by 13.4 lb., as follows:
>
> $$\Delta D_i = (310)^2/1.28\pi[(1/[29.5]^2 - 1/[41.3]^2)] = 13.4 \text{ lb.}$$
>
> That is considerable; it increases our rate of descent by
>
> $$\Delta w = v(D_i/L) = 1.42 \text{ ft. per sec.}$$
>
> and it is just this value which determines whether we can compete.

The large span was granted at last. Its success was so convincing that, in the following year, out of 53 entries, 33 had a span of 36 ft. or more; 19, a span of 40 ft. or more; and 11, a span of 45 ft. or more. One, a monoplane built by Espenlaub, a young village carpenter, had even a 55.8-ft. span and, in spite of a bad finish, showed a very good performance.

SECTION AND BEST-CHORD DETERMINATION

The next thing to determine was a good section. I wished to find a section with a low D_s/L ratio for f. The Goettingen section No. 427, illustrated in Fig. 4, is very good. At $K_y = 0.95$, it has a ratio of 1/87 only. However, it is very thin. For structural and for service reasons, I wished to use a thick section. Also, the section in Fig. 4 had rather low lift-values, and would have required more wing area than I wished to use. Of the thick sections available, Goettingen section No. 441 looked promising. It showed a very high lift and a good ratio, about 1/50 over a wide range and especially for the high lift-values, with a minimum near $K_y = 1.0$. It was almost thick enough for internal bracing, but it was desirable

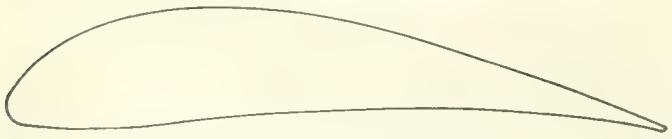


FIG. 5—THE COMPOSITE WING SECTION USED IN THE HANNOVER SAILPLANE

to make it a little thicker anyhow. To save time, Dr. Betz, of Goettingen, advised us to form a new section by combining the existing templates of Goettingen sections No. 384, upper side, and No. 441, lower side. The section No. 482 so obtained was tested and developed to be very satisfactory. It had almost the same properties as Goettingen section No. 441. The maximum thickness is 18 per cent of the chord. Such an ample thickness permits the construction of a very stiff, internally braced wing of sufficiently low weight. It is shown in Fig. 5.

The next problem to solve was that of finding the best chord. This means the chord that will give the minimum rate of descent, w. The best value of c_1 is found by differentiating w for c_1 and setting $dw/dc = 0$. This gives, for the monoplane,

$$c_{1best} = 0.5\pi[(fs \pm \sqrt{f^2s^2 + (12A_1/\pi)}\,]$$

FIG. 6—PLAN VIEW OF THE WING USED IN THE HANNOVER SAILPLANE

For the biplane having a gap-span ratio of 1 to 10,

$$c_{1best} = 0.6\pi[(fs \pm \sqrt{f^2s^2 + (10A_1/\pi)}\,]$$

The chord that gives the best gliding-angle is smaller. For the monoplane

$$c_{1best} = \sqrt{\pi A_1}$$

For the biplane with a gap-span ratio of 1 to 10

$$c_{1best} = \sqrt{1.2\pi A_1}$$

These formulas for the best chord are surprisingly simple. They *contain* nothing but three values that can be estimated or determined in the early design; the span, s; the D_s/L ratio, f; and the apparent parasitic area, A. We had the following values:

s, ft.	41.3
f	1/55
sf	0.75
Cross Area of the Body, sq. ft.	6.5
Estimated Drag Coefficient	0.20
Area of Tail Surfaces, sq. ft.	34
Estimated Drag Coefficient	0.012
$A_1 = (6.5 \times 0.20) + (34 \times 0.012)$	1.71

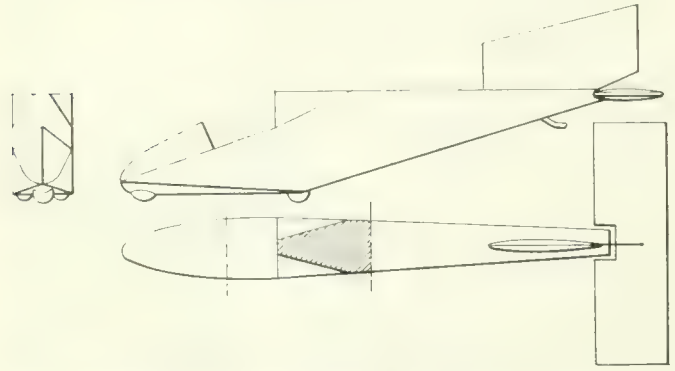


FIG. 7—END AND SIDE ELEVATIONS AND PLAN VIEW OF THE BODY OF THE HANNOVER SAILPLANE

The best apparent chord of the monoplane is, therefore.

$$c_{1best} = 0.5\pi[0.75 \pm \sqrt{(0.75)^2 + (12/\pi \times 1.71)}\,]$$
$$= 5.35 \text{ ft.}$$

For the best gliding-angle,

$$c_{1best} = \sqrt{1.71\pi} = 2.32 \text{ ft.}$$

A close investigation, details of which are given in the Appendix to this paper, shows that the most advisable chord lies between the so-determined optima. At $c_1 = 4.2$ ft., the rate of descent is only 1.4 per cent more than the minimum, but the gliding angle is 12 per cent better than for $c_1 = 5.35$ ft. At $c_1 = 2.32$ ft., on the other hand, the gliding angle would have been still better but, also, the rate of descent would have been 20 per cent worse.

MONOPLANE OR BIPLANE

A further investigation, as explained in the Appendix, shows that in the case of a biplane a slightly smaller span would be sufficient to bring the same results. With the thick section No. 482, a span of 1 ft. would be spared and, with the very good section No. 427, a span of even 5 ft.

I thought that such a small gain in span would not make the biplane preferable. The biplane requires twice as many beams and many more ribs and fittings, and wires and struts which can be avoided in the monoplane. This consideration applies especially to the very thin section No. 427 that is so very good aerodynamically. I doubt if a wing with this section could be constructed with only one pair of struts on either side.

The investigation showed also that the chord of the biplane would have to be very small, about 2.2 to 2.7 ft. It is certainly not impossible to build such narrow wings; in the case of very large craft, it has even the advantage that the elements of which the wings are composed are handier than those of a monoplane with a larger chord. For instance, they still can be shipped by railroad, while the corresponding monoplane has to be transported by air. In such a case, a very careful comparison will be necessary to balance the merits of the two types.

This analysis is, however, sufficient to show that a more conventional type of biplane, with shorter span and longer chord, would not have been able to compete with the monoplane. I gave the wing an area of $A = sc_{mean} = 41.3 \times 4.2 = 174.0$ sq. ft. It is slightly deeper in the center; the ends are tapered and decrease to the good section No. 427 at the wing tip, as shown in Fig. 6.

It is of some interest now to determine the total amount of the rate of descent and the gliding angle, and to subdivide the latter. The gliding angle consists of the following parts of the

			Per Cent
Parasitic Drag, $A_1/(c_1s)$	$= 1.71/174$	$= 0.0098$	$= 16.3$
Induced Drag, $c_1/(\pi s)$	$= 4.2/41.3\pi$	$= 0.0324$	$= 53.7$
Section Drag, f	$= 1/55$	$= 0.0182$	$= 30.0$
Total Gliding Angle, tan γ	$= 1/16.6$	$= 0.0604$	$= 100.0$

With a lift $L = 430$ lb. and in the standard atmosphere $\rho = 1/422$ (lb. $\times$ sec.^{2}/ ft.^{4}), the best speed for soaring would be

$$v_{best} = \sqrt{(2 \times 430 \times 422)/174} = 45.6 \text{ ft. per sec.}$$
$$= 31.1 \text{ m.p.h.}$$

This gives a rate of descent of

$$w_{best} = v \tan \gamma = 45.6/16.6 = 2.75 \text{ ft. per sec.}$$

I was very much surprised by the result of the subdivision of drags. I had not expected that the wing with the "obviously somewhat large span" would produce so

much induced-drag, 54 per cent of the total drag, and that the parasitic drag would be so little, only 16 per cent. Of course, there were no struts, wires, axles and wheels, but the tail surfaces and the body were large for a small sailplane of only 174 sq. ft. Also, considering the rough form of the body, a large drag coefficient, 0.20, was used in the analysis; good forms have less than 0.06.

In regard to the reason the wing was not braced externally, a streamline tie-rod on either side would not have affected the performance to any extent. I omitted them, not so much for the saving of drag as for manufacturing and service reasons. In my letter of April 30, 1921, I wrote, "If there is the slightest chance, I will try to avoid external bracing, not so much to save drag as for the simpler assembling." It is obvious that wires and wire connections are in constant danger because of the rough handling that a glider must withstand during transportation over a rolling country.

Form and Arrangement of Body

The body is shaped somewhat oddly, as indicated in Fig. 7 and shown in Fig. 8. No effort was made to give it streamline forms. It is square in the rear, ending in a horizontal knife-edge. It is hexagonal in the front, with straight sides and sharp edges running from front to rear; and they even do not run steadily, but are broken below the wing. The lower break is below the center of gravity to allow a 16-deg. tilting fore-and-aft, as wheels do. The upper break occurs at the trailing edge of the wing and, from there, the upper longerons run straight down to the nose to give sufficient free space for the pilot. I determined the form of the body principally for constructional reasons.

One very important point had been considered with reference to the arrangement of the body. A series of experiments in the wind-tunnel of Dr. Junkers, at Dessau, in 1920, had demonstrated that, for the condition of high lift, a body below the wing is much superior to a body on top of it. This is not so important for fast airplanes, flying at double landing-speed or more, but it is of high importance for the very low-power airplanes. It developed that in many cases the drag of the entire airplane is much more than the sum of the detail drags. I took the precaution, therefore, to place the body below the wing; and to leave the entire upper side and the front third of the lower side free from obstructions.

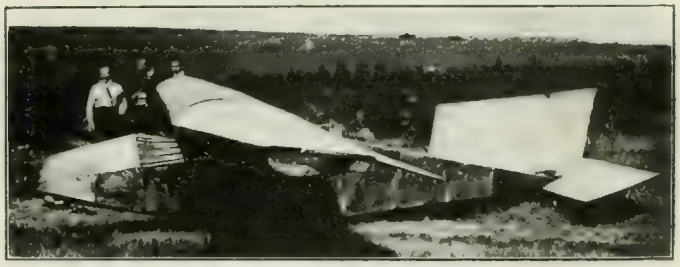
Another lesson learned from Dr. Junkers' experiments was that the near surroundings of the wing must be free from pockets in which the air speed has to decrease. This was carefully avoided. The joint between the body and the wing begins just behind the pilot's head, one-third of the chord from the leading edge, and widens constantly to the full width of the body at the trailing edge.

Model Test

A model test was run at Goettingen. The following arrangements were tested:

(1) Standard wing model, to determine properties of section
(2) Model of the intended wing, tapered, to 1/10 scale
(3) Model of the entire sailplane, with the elevator adjusted for every angle of incidence so as to balance the craft about the estimated center of gravity
(4) A similar test to (3), but with a round streamline body

Test (2) confirmed Prandtl's theory of induced drag well, and the results were even slightly better than those transformed from Test (1), as shown in Fig. 9. Test (3) gave the somewhat surprising result that the parasitic drag is not constant. At low angles of incidence, it is very bad. The wing is here very bad also, particularly below $K_y = 0.4$, where a lower burble-point is reached. (See Fig. 10.) On the other hand, the parasitic drag



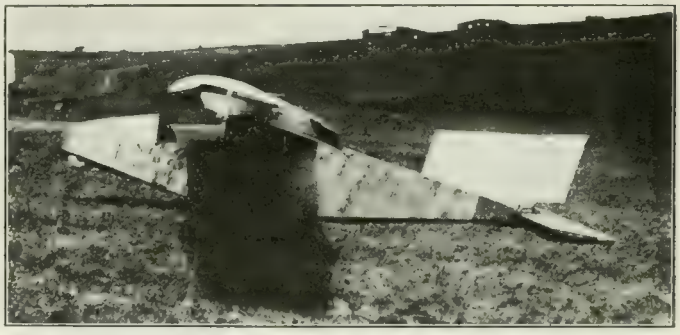


Fig. 8—Two Views of the Hannover Sailplane Showing the Somewhat Peculiar Shape of the Body

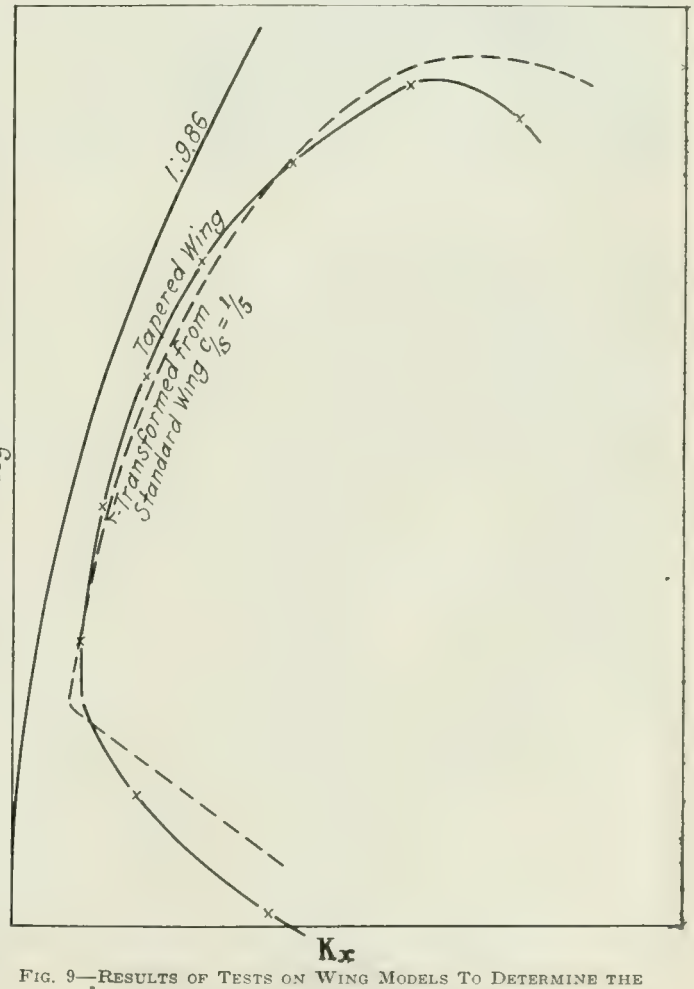


Fig. 9—Results of Tests on Wing Models To Determine the Properties of the Sections

disappears at very high lift and, therefore, the lowest rate of descent does not occur at $K_y = 1.0$, as the analysis had determined, but at $K_y = 1.36$, with a gliding angle $\tan \gamma = 1/15$. This determines the best speed for soaring to be

$$v_{best} = V\ (2\times430\times422)/(174\times1.36)$$
$$= 39.2 \text{ ft. per sec.}$$
$$= 26.7 \text{ m.p.h.}$$

It determines also that the minimum rate of descent is

$$w_{best} = v \tan \gamma = 39.2/15$$
$$= 2.61 \text{ ft. per sec.}$$

Another more surprising result was the failure of the streamlined body, Test (4), to give better results. It was even slightly inferior for high lift. The only explanation that we could imagine was the more complicated joint between the round body and the wing. At any rate, this is a typical example of costs having been saved by making a laboratory test.

Constructional Details

The question may arise as to why, with the knowledge that the round streamline body of Test (4) did not give better results, we did not discard the body entirely. I am glad we have not discarded it, because it has helped considerably to beat the record. In the Hannover sailplane the pilot is enclosed entirely; nothing but his head protrudes from the body and he is well protected from the wind and cold, as shown in Fig. 11. Hentzen reports that he felt comfortable during his great flight, while the spectators on the ground built fires to warm themselves. We have not had any bad crash, but I believe that if we had had the pilot would have found good protection in the

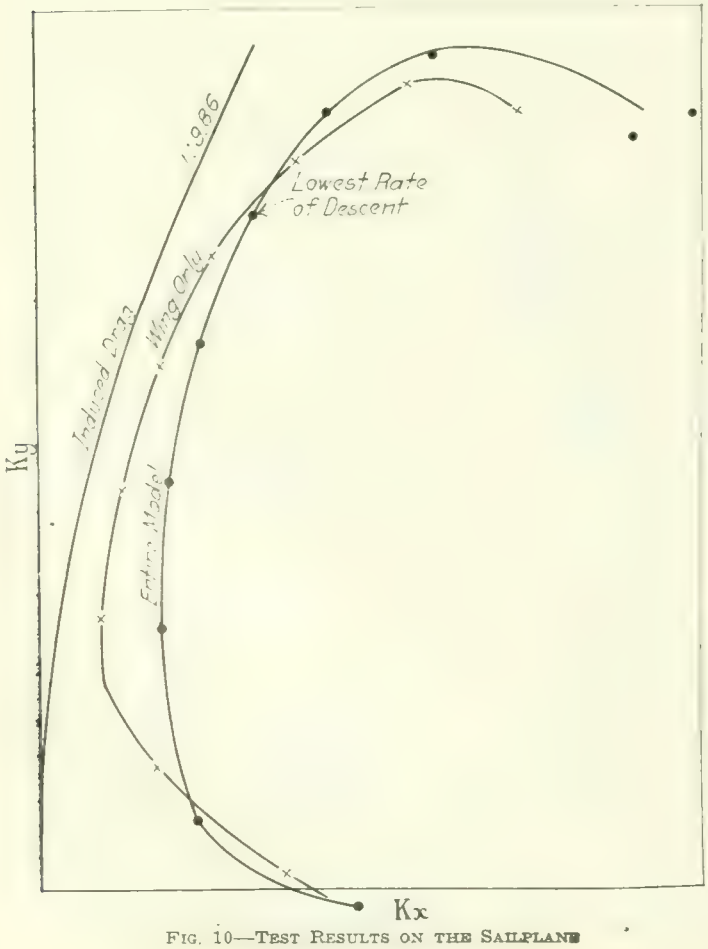


Fig. 10—Test Results on the Sailplane

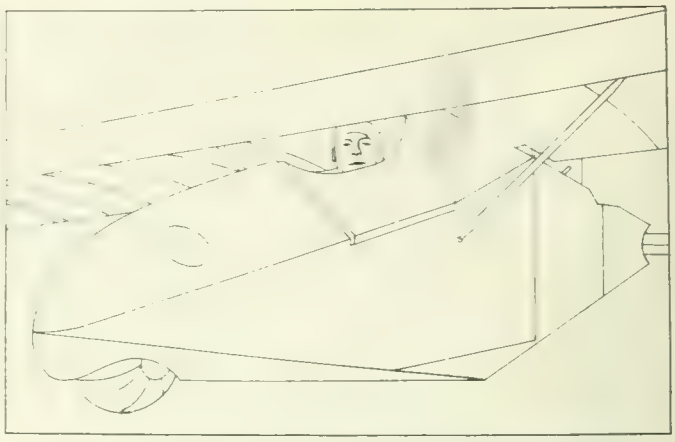


Fig. 11—The Pilot in the Hannover Sailplane Was Well Protected against the Wind and the Cold

body. Plywood bodies are the most crashproof, especially with ash longerons that are wrapped with fabric. Our longerons are laminated and form an uninterrupter bow in the nose; they absorb much energy before destruction and do not splinter so badly as spruce.

A feature which helped very much to avoid crashes was the "football wheel," suggested by Herrmann Dorner, well-known designer of aircraft and chief engineer of the Hannover Wagon Co. This is a rimless wheel in which the inner tube is ball-shaped and rides on the hub; the casing is connected to the flange of the hub. This wheel worked very satisfactorily.

The construction of the wing is somewhat similar to that of Fokker's wing, or its predecessor of 1916, an all-wood cantilever wing designed by Dr. Oesterlen of the Hannover Institute of Technology. It contains no internal wire-bracing or metal fittings; metal is used only where the outer and the center wing join. A three-ply cover of the front third forms the skin and the drag bracing; the rear two-thirds of the wing is made in the usual way, and the ribs are covered by doped fabric. The new feature of this wing is that it does not contain the classic arrangement of a front and a rear beam; it has one single beam only, one-third of the chord from the leading edge, where the section has its greatest depth.

Some constructional problems arise from this new arrangement. The ribs have to cantilever toward the trailing edge for two-thirds of the chord. However, this is for 3 ft. only, which is not more than the rear cantilever part of an ordinary medium-sized rib. Also, as the beam is 11 in. high, the free length is not out of proportion.

Torque

A more difficult problem was how to master the torque that tends to tilt the wing forward at high speed. At low angles of incidence, in all cambered wings, the nose part gets a down-pressure while the rear has still an up-pressure. The single beam is not able to carry the moment that results therefrom. It carries only the forces in its plane. The torque moment turning about the beam is taken by the plywood-tube that forms the cover of the front third of the wing. The value of this moment is

$$M_t = qA\ (-aK_n + bK_t + cK_m$$
$$= qAcK_{m_1} \text{ in abbreviated form according to Fig. 12}$$

The coefficients K_m, K_n and K_t are taken from the test of the bare-wing model. The value of the dynamic pressure q is found from

$$q = W/[A\sqrt{(K_y^2 K_x^2)}]$$

The coefficients K_y and K_x are taken from the test of the entire model. We find, by the elimination of q, that

$$M_t = (W \times c)[\{-(a/c)K_n + (b/c)K_t + K_m\}/\sqrt{(K_y^2 + K_x^2)}]$$

This is the formula that determines the worst possible case of a torque moment. The moment can reach very high values, especially for fast airplanes. It has made many wings collapse during a dive. We had very fortunate conditions in the Hannover sailplane regarding the speed limit. At low angles of incidence, below the lower burble-point, the drag is abnormally high. The minimum value of $\sqrt{(K_y^2 + K_x^2)}$ is 0.092, which is twice as much as in ordinary airplanes. The speed limit for a long steep dive is, therefore, not more than

$$v_{max} = \sqrt{[2W/\{A\rho\sqrt{(K_y^2 + K_x^2)}\}]}$$
$$= \sqrt{(2 \times 430 \times 422)/(174 \times 0.092)}$$
$$= 150 \text{ ft. per sec.} = 102 \text{ m.p.h.}$$

This speed limit has, naturally, never been reached. However, the pilots claim that they have reached a speed of 56 m.p.h. in a dive, which should warn them not to be careless in the consideration of the high-speed condition.

Returning to further consideration of the torque moment, the moment coefficient

$$K_{m_1} = [-(a/c)K_n + (b/c)K_t + K_m]$$

which, in our case, is

$$K_{m_1} = (-0.33\,K_n + 0.10\,K_t + K_m)$$

has its maximum near $\gamma = -4.6$ deg. and is $K_{m_1\,max} = 0.130$. If the sailplane dives for a long time so that it reaches its speed limit, and then is tilted up to the angle of incidence $\gamma = -4.6$ deg., the torque moment about the beam axis becomes

$$M_t = 430 \times 4.75 \times (0.130/0.092)$$
$$= 2890 \text{ lb-ft.}$$

This is the largest moment that has to be carried from the wing into the body and balanced by the elevator or tail surface. The largest torque-moment of each wing near the root is one-half of this value.

Concerning a torque-tube analysis, our knowledge of the torque moment did not allow us to determine the required wall-thickness of the plywood tube without a test. No information could be obtained in regard to the shear-strength of plywood under such conditions as obtain in the nose of the wing. Under ordinary conditions, the shear-strength of plywood is about $t = 2500$ lb. per sq. in. The circumscribed cross-area of the tube is $A_c = 1.1$ sq. ft. A factor of safety of 2.5 seemed advisable. The required thickness under these assumptions would have been

$$th_{req} = (FS \times M)/(2 \times A_c \times t)$$
$$= (2.5 \times 1435)/(2 \times 1.1 \times 2500 \times 12)$$
$$= 0.055 \text{ in. near the root.}$$

Toward the tip, the thickness would have tapered down.

Static Tests and Factor of Safety

We made a torque test on a piece of beam with its ribs and the nose covered with 1/16-in. birch plywood. The sample first stood-up very well and showed little deformation. Then the plywood began to wrinkle; it lost much of its stiffness and sheared finally along a rib and the beam. Although the test did not show the full required strength, it gave us valuable information about the way in which such a structure is destroyed. The phenomenon of wrinkling under shear is very much similar to that of a slender strut bending under a longitudinal load. Unfortunately, no second Euler has yet arisen to bring the problem to a simple solution.

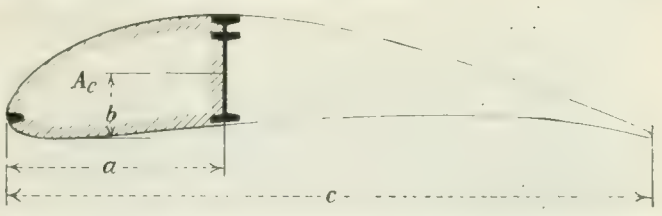


Fig. 12—Diagram Illustrating the Determination of the Torque Moment about the Beam Axis

We brought the ribs closer together to reduce the free wrinkling length, and increased the plywood thickness to 0.08 in. in the center. Toward the wing-tip, it tapers down to 0.063 and to 0.048 in. in thickness. The sample was repaired and another test was made to determine the bending-strength of the beam. It brought no new knowledge; however, it helped us to feel confident about the strength of the wing. A factor of safety of 5 for a uniformly distributed load had been assumed. Another case, which we considered, was that a load equal to the weight of the sailplane would apply to one wing-tip. This case corresponds to a bad landing in which the sailplane touches the ground first with one wing-tip, a case which is not very rare in a rolling country subject to treacherous winds. It was possible, therefore, to lift the loaded sailplane on its wing-tips, with a factor of safety for this abnormal condition of $FS = 2$.

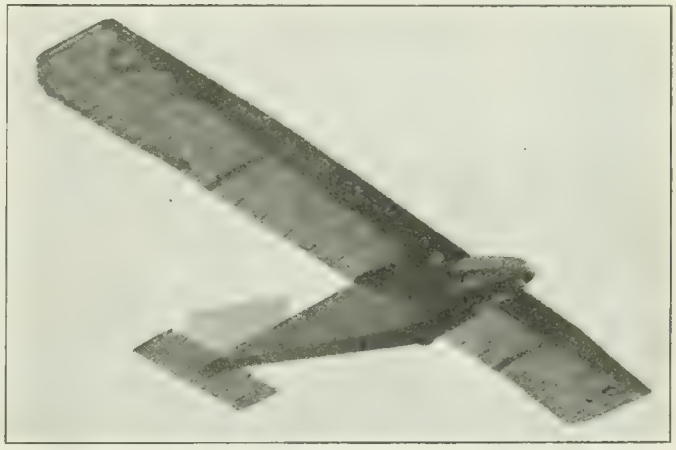


Fig. 13—The Hannover Sailplane in Flight

The question has been raised whether such a high fac-

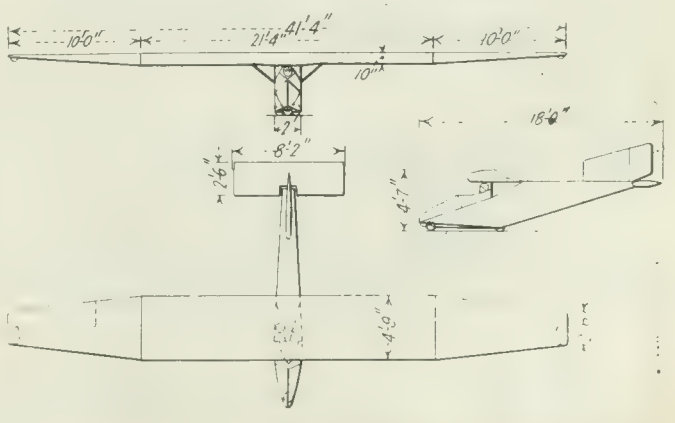


Fig. 14—Plan View with Dimensions of the Hannover Sailplane

tor of safety is justified. When asked for my opinion May 1, 1921, I wrote

> Stunting will come soon and will result in high stresses. It will not be long before air combats will be practised, perhaps not in Germany but certainly in other countries. Also, when we glide in a flat country and raise a sailplane as a kite, to release the towline and glide after the altitude is reached, we shall have to meet large stresses
>
> It is impossible to save much weight by a reduction of the factor of safety; the wing loading that we have to use is too low for that. It is hardly possible to construct any lighter than now. Also, the useful load is such a large percentage of the total load that a saving in the dead-load will not help much

Conclusion

The Hannover sailplane was the heaviest of all the competitors in 1921, at least of those competitors that flew. If all of the features that have been incorporated in it are considered, it will be understood that it could not be very light. But it is evident that the departures from conventional practice brought more gain in aerodynamical property than loss by weight.

The result was a sailplane of very high efficiency; it flew longer and higher and farther than the other competitors. It flew longer, because it could continue to fly when the up-current had become too slow for the others. It flew higher, because it could keep aloft in a wind less deflected upward by the hill. It flew farther, because it had a better gliding-angle. The competitors of 1922 that were next successful were all very similar to this type of 1921.

The Rhoen meeting gave us the opportunity to try radical departures from the conventional practice at moderate cost. These were the football wheels, the body of unusual form and arrangement, the large span, the single beam and the torque-carrying plywood-cover. We were glad to be rewarded with the Kyffhaeuser prize for the wing of best design. Fig. 13 shows the sailplane in flight; and Fig. 14 is a plan view giving dimensions.

Appendix

To find the best chord for the rate of descent, we transform the formula previously given for w and we have

$$w = [\sqrt{(2L/\rho s)}]\ [A_1 c_1^{-1.5} + c_1^{1.5}/\pi + fsc_1^{-0.5}]$$

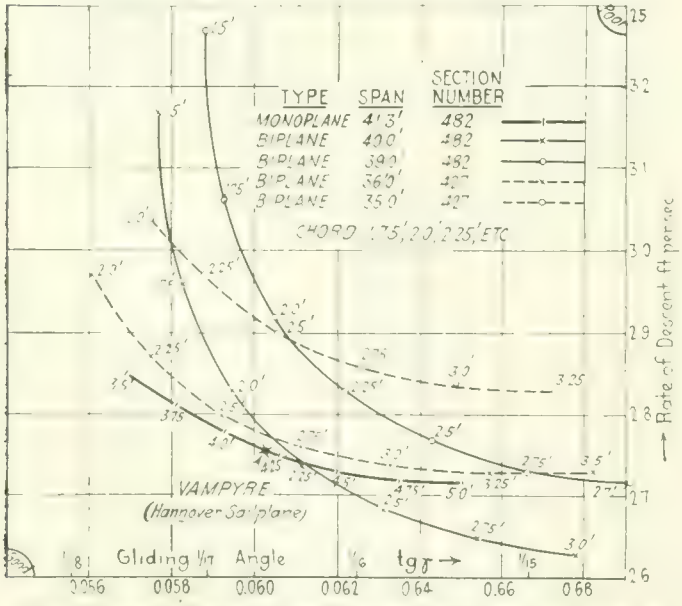


Fig. 15—Chart Showing the Gliding Angle and the Rate of Descent for Various Chords

Differentiating w for c_1 and setting $dw/dc_1 = 0$, we have

$$0 = -1.5\,A_1(c_1^{-2.5}) + 0.5\,\pi\,(c_1^{-0.5}) - 0.5\,fs\,(c_1^{-1.5})$$

We transform the above equation to the form

$$c_1^3/\pi - fsc_1 - 3A_1 = 0$$

Solving this last equation we have, for the monoplane,

$$c_{1\,best} = \pi/2\ [fs \pm \sqrt{(f^2s^2 + 12A_1/\pi)}]$$

For the biplane with a gap-span ratio of 1 to 10, we replace π in the equation just given for $c_{1\,best}$ by 1.2 π. This is the upper limit for the chord.

To find the best chord for the gliding angle, we transform the formula previously given for tan γ and we have

$$\tan\gamma = 1/s\ [A_1(c_1^{-1}) + c_1/\pi + fs]$$

Differentiating tan γ for c_1 and setting $d\tan\gamma/dc_1 = 0$, we have

$$0 = -A_1(c_1^{-2}) - 1/\pi$$

We transform the above equation to the form

$$c_1^2/\pi - A_1 = 0$$

Solving this last equation we have, for the monoplane,

$$c_{1\,best} = \sqrt{\pi A_1}$$

For the biplane with a gap-span ratio of 1 to 10, we replace π in the equation just given for $c_{1\,best}$ by 1.2 π. This is the lower limit for the chord.

To find the advisable chord for a monoplane, the gliding angle and the rate of descent are determined for a series of chords between 3.75 and 5.00 ft., as follows

The gliding angle

$$\begin{aligned}\tan\gamma &= A_1/c_1s + c_1/\pi s + f\\ &= 1.71/41.3c_1 + c_1/41.3\pi + 0.0182\\ &= 0.0414/c_1 + c_1/130 + 0.0182\end{aligned}$$

The rate of descent

$$\begin{aligned}w &= [\sqrt{(2L/\rho\, c_1 s)}]\tan\gamma\\ &= [\sqrt{(2\times 430\times 422)}/41.3c_1]\tan\gamma\\ &= (93.5/\sqrt{c_1})\tan\gamma\end{aligned}$$

The values for the series of chords are given in Table 1.

TABLE 1—VALUES OF THE GLIDING ANGLE AND THE RATE OF DESCENT FOR A SERIES OF CHORDS

Chord of Wing ..		c	3.75	4.0	4.25	4.5	4.75	5.0
Apparent Chord		c_1	3.75	4.0	4.25	4.5	4.75	5.0
Drag/Lift	Parasitic	0.0414/c_1	0.0110	103	97	92	87	83
	Induced....	c_1/130	0.0289	308	327	347	366	385
	Section.....	0.0182	0.0182	182	182	182	182	182
Gliding Angle		tanγ	0.0581	593	606	620	635	650
Rate of Descent		w	2.81	2.78	2.75	2.73	2.72	2.72

The results in Table 1 are plotted in Fig. 15, w/tan γ. A chord c = 4.2 ft. gives a good result for both w and tan γ, and is still structurally reasonable.

Monoplane and Biplane Comparison

The results with the monoplane are compared with those of biplanes, as follows. The biplanes have a smaller span and either the same wing-section No. 482, in which f = 1/55, or the thin section No. 427, in which f = 1/87. They have an additional parasitic-drag due to the struts and wires. We have

ΔA_1 = Number x Length x Thickness x Drag Coefficient

This gives a total parasitic-drag area of

	Sq. Ft.
$A_1 = A_1 0 = (6.5 \times 0.20) + (34 \times 0.012)$	= 1.71
$+\Delta A_1 = +8 \times 3.5 \times 1/20 \times 0.27$	= +0.38
$= -8 \times 13 \times 1/150 \times 0.40$	= +0.27
	2.36

Hence, A_1 = 2.36 sq. ft.

The performance values of the biplane are found in the same way as they were determined for the monoplane. For instance, the one with Section No. 427 has the following values

$$f = 1/87 = 0.0115$$
$$K_y = 0.9$$
$$c_1 = 2 \times 0.9 \times c$$
$$s = 36 \text{ ft.}$$

We have, for the gliding angle

$$\tan \gamma = A_1/c_1 s + c_1/1.2\pi s + f$$
$$= 2.36/36c_1 + c_1/1.2\,\pi \times 36 + 0.0115$$
$$= 0.0656/c_1 + c_1/136 + 0.0115$$

For the rate of descent, we have

$$w = [\sqrt{}\,(2L/\rho\, c_1 s)\,] \tan \gamma$$
$$= [\sqrt{}\ (2 \times 430 \times 422)/(c_1 \times 36)\,] \tan \gamma$$
$$= (100.3 \times \tan \gamma)/\sqrt{c_1}$$

The results are plotted also in Fig. 15, together with those of the monoplane, $w/\tan \gamma$. It develops that with the thin section No. 427, a biplane of about 36.2-ft. span and having a 2.65-ft. chord would give the same gliding-angle *and* the same rate of descent. With the thick-wing section No. 482, used in the monoplane, a span of about 39.2 ft. and a chord of about 2.15 ft. would be required.

CLOSED-CAR DEMAND INCREASING

THE marked trend toward an increased use of closed cars is indicated by the replies to a questionnaire recently sent out by the National Automobile Chamber of Commerce. This was circulated among 20,000 car-owners and 60 per cent of the replies stated the buyer's next purchase would be an enclosed model. The principal reasons given in the replies were protection from the weather, general comfort, all-year use and a better appearance. In Massachusetts, Illinois, Wisconsin, Iowa, California and Pennsylvania the vote for the closed car was well over 60 per cent while in the Southern States the demand was less marked, only 40 per cent of the owners in Alabama, for example, being in favor of the closed car.

A large number of the replies gave several reasons for the owner's preference. Protection from the weather was listed as one of the factors in 44 per cent of the replies, although general comfort, which ranked next with 34 per cent of the replies, includes not only protection from the weather but also freedom from dust as well as easy riding qualities. In mentioning economy, which represented the main reason in 20 per cent of the replies, some of the owners emphasized the point that in addition to being able to use the enclosed car throughout the entire year, the expense of extra heavy clothing needed for the open models for use in the winter time was eliminated. The inconvenience of side curtains was mentioned by 4 per cent of the owners preferring closed cars as the reason why their next purchase would be a closed vehicle.

On the other hand, the answers to the questionnaire revealed several strong factors that will keep the open models in popular favor. These include poor roads which was mentioned by 23 per cent of the replies as being an objection to closed cars; the price differential, lightness, safety, more air and business utility. Although the price differential is much less now than it was 2 or 3 years ago, 16 per cent of the replies gave this as the reason for purchasing an open type of automobile. Lightness with a resulting lower upkeep cost was emphasized by 15 per cent. Closely following these two factors was the unforeseen argument of safety. In the replies favoring the open car 14 per cent of the owners gave this as a reason expressing a fear of cuts resulting from broken glass and an objection to being closed in in case of accident. The fresh-air advocates were represented by 13 per cent of the replies and 10 per cent emphasized the utility of an open car for business use. The replies from the farming districts in particular indicated that the phaeton was more of a utility vehicle as it can be readily used for cartage and it is also possible to drive it over fields with less inconvenience than would be the case if an attempt were made with a closed car.

FRENCH TEST OF PRODUCER-GAS TRUCKS

FIRST prize in the French gas-producer trials has been won by the British entrant, the Thornycroft suction gas vehicle. The six competing trucks used four-cylinder engines designed to run on gasoline. Four of the trucks employed charcoal as fuel; the other two, a mixture of one-fifth charcoal and four-fifths wood.

The competition showed that with an engine designed for gasoline, there was a loss of power when gas was substituted. Taking the power of the gasoline engine as 1, with producer gas the power would drop to between 0.50 and 0.73 if the engine were not altered in any way, and to between 0.70 and 0.90 if changes were made in the compression, size of valves or areas of valve-openings and gas passages. It has been considered that the results of the trials show that there is an economy of 25 per cent in the use of gas compared with gasoline.

The Thornycroft powerplant differs essentially from others on the market in one or two features. The steam is produced in a separate generator, which is not attached to the producer, by heat from the engine exhaust on the principle that the heat of the exhaust gases must necessarily be proportionate to the power developed, and thus the amount of steam can be made proportionate to the working. This generator can be detached from the engine and entirely taken to pieces for cleaning, which is a point of very great importance. The Thornycroft powerplant is intended primarily for use with the chassis of the British War Office pattern, known as the J type, and is designed as an integral part of the machine. Consequently, every part is easily accessible, in no way interfering with the fitting of an ordinary cab or body and detracting but little from the appearance of the vehicle. Moreover, the weight can be cut down to a minimum.

Generally speaking, the engine can be started on gas in less than 10 min. from cold, after which it is said that the car can be left standing for an indefinite period, the engine idling, with a certainty of starting away as soon as the throttle is opened, whatever the load.

No water is used for the cleaning or scrubbing of the gases, and cleaning is thereby much simplified, while the possibility of any corrosion or electrolytic action taking place is eliminated.

The Problems in Front of the Automotive Engineer

By C. F. Kettering[1]

Dayton Section Paper

MR. KETTERING mentions present practice with regard to engineering education and states that there is beginning to be a realization that such a great amount of specialization is not necessarily accomplishing the best results. He makes a plea for greater consideration by the engineer of the two fundamental factors, the economic determination of the details of design and the appeal to the final purchaser as being pleasing to him in performance, comfort and utility, because the difference between present and former automobiles is not in principle but in the way the materials used are arranged with respect to each other.

Following a brief general discussion of the transfer of energy in which he also advocates making a greater use of research methods and the data obtained in other lines of endeavor, Mr. Kettering then comments upon some of the constituents of car development, placing emphasis upon the necessity of providing an appeal to the user, and concludes his paper with a brief resume of cost considerations.

THERE is a marked similarity between the problems now confronting automotive engineers and their reaction to them, and the problems in front of the engineers of every other phase of engineering. This condition is so general that those in charge of engineering education are giving more study to the organization of their courses, and are questioning the values of the subjects taught and the methods of teaching them in a way that has not occurred for many years. This is the general condition of all engineering schools and must be considered as a reflection of the condition that all types of engineers are being called upon to meet.

At the present time, engineering education is very highly specialized. Young men intending to go into one branch of engineering take different courses from different instructors than other men in the same institution who are expecting to go into engineering work that is classified as being slightly different. There is beginning to be a realization that this large amount of specialization is not necessarily accomplishing the best results.

The undergraduate has a smattering of details applying to his own specialty, these details being usually outofdate before he is in a position of sufficient responsibility to be able to apply them; and, too frequently, he does not see the general foundation upon which he works, which is really the foundation on which all engineering work is done.

When we look at the problems that the engineer has to meet today, we find, finally, when we judge his work, that the thing which he has really done is simply a rearrangement of the material used. The difference between the automobile of today with its high degree of performance and the automobile of 1904, is not a difference in principle, but a difference in the way the materials used are arranged with respect to each other. This involves not only a reproportioning of parts, but also, to a much larger extent than we usually realize, the rearrangement of the molecules that go to make up the materials from which these parts are made. We have new materials today, and can get the same materials at a lower price which were not available to the engineer of 1904 and, as a result, we can get a new and, in our opinion, a better result by taking advantage of the situation. When the engineer begins to rearrange these materials, he has two factors of fundamental importance to keep in mind and, if he fails, it will be because he has neglected to take the proper account of one or the other. The first factor is, the economic determination of the details of the design; that is, the arrangement of the proportion of the parts in their relation to each other, so that the performance specifications are met with the least amount of material which has been subjected to a minimum cost of fabrication.

It is not enough, however, to have produced the most economical design, if that completed design does not appeal to the final inspector, the final purchaser, as being pleasing to him in performance, in comfort and in utility. A designer may accomplish some wonderful feat of performance in the design of an automobile; but if this performance does not bring any satisfaction to the owner of the vehicle, or if this performance cannot be obtained without discomfort to himself, or sometimes, what is of more importance, without pleasure to his wife, he will not buy the product and the design will be a failure.

When the engineer commences to study the possible rearrangement of material that will enable him to obtain a better or more economical result, he must first remember that materials are used in general for two purposes. The first of these is to prevent motion; and the action of the material may be considered as mainly static. A bridge or the frame of a machine obviously is of this type; the main purpose of the frame of the automobile is to prevent relative motion of the various parts. The other use of materials is to facilitate motion or, perhaps, better to guide motion and to transmit energy. The automobile, as a complete assembly, is of this type; but within the automobile, the piston is, of course, a piece of material used to transmit the motion of the expanding gases in such a way that the motion of the car itself can be obtained from it.

Transfer of Energy

All transfers of energy involve the product of a force and a velocity. The velocity, obtained as a result of the action of the farce, is limited always by two factors: (*a*) the resistance to the overcome and (*b*) the inertia to be accelerated. After the motion has become uniform, the only factors involved are the applied force and the resistance restraining the motion due to that force.

The electrical engineer is early taught Ohm's Law. It is that the current is equal to the voltage divided by the resistance and we write it thus, $I = E/R$. We look at that as a statement of a law applied to the electrical engineer only and too often forget that it is a law of universal application and might simply be stated, velocity

[1] M.S.A.E.—President, General Motors Research Corporation, Dayton, Ohio.

equals force applied, divided by resistance to motion. This is the equation that determines the maximum speed obtainable from an automobile and is just as true on the road or on the racetrack, as is Ohm's Law in the electrical circuit.

The question of how fast energy can be transferred from one point to another, or from one body, say, a mass of flaming gases in an automobile cylinder, to the energy dissipated in the air and on the road by the speeding car, depends entirely upon the properties of the materials involved and their arrangement. These properties are inertia, elasticity, and resistance to relative motion, which we call friction.

Too often the engineer does not understand the meaning of inertia. Very early when studying physics, he had considerable trouble with a subject called the laws of gravitation, and too often he did not realize when studying these that what he was really studying was the laws of accelerated motion, in the special case where the accelerating force is the attraction of the earth; and that the really important things he could get from this had only incidentally to do with gravitation and with weight; that the important things were force, inertia and the resultant motion coming from the application of the force to the inertia under different conditions as to frictional restraint. It would not have taken us nearly as long to work from the design of 1904 to a design similar to that of 1922, if the fundamental importance of these factors in every energy translation had been realized.

It will be worthwhile to digress for a moment and point out how scientists working in one line of research have had to take account of the methods and the information available in other lines to accomplish the results that are being accomplished today. The general public thinks of the Mount Wilson Observatory as a place where men spend their time watching the stars with great telescopes. There is, of course, today a great amount of cataloging and study of motions going on, which was the only work of the early astronomer; but by far the greater part of the work of an institution of that kind is along lines that the early astronomer never dreamed of and would have considered ridiculous had anyone been able to tell him of them.

What they are doing at Mount Wilson today is studying the spectrum of the elements under all conditions of pressure and motion; under all conditions as to magnetic and electrostatic fields that they are able to devise. The motion of the stars is determined by photographs, taken from time to time, which can be compared at the convenience of the astronomer. The work of mapping the heavens has been greatly simplified by the use of photography, and the energies of the astronomer released to permit attacking problems involving the structure of matter. The solution of these problems will have a very great effect in everyday life. The methods that are being used are methods developed by the physicist and the physical chemist, and are very far removed from the methods that were used by the astronomer of a few decades ago. The automotive engineer must follow the lead of the astronomer and borrow other methods to supplement those he has used up to this time, if he is to progress as he must to meet the new conditions.

Returning to our question of falling bodies, we find that the so-called laws of falling bodies are really laws of the transfer of energy, involving the application of force to inertia. The potential energy that a body formerly had by reason of its position is transferred to the inertia energy it has by reason of its motion. If the body falls through a dense fluid like water, the velocity is much less than if it falls through the air, and this velocity soon becomes uniform, the velocity being determined by the formula $V = F/R$, just as in the case of the electric circuit, where $I = E/R$. If the body is restrained by an elastic element such as a spring, we have energy stored in this spring, just as we have energy stored in an electric condenser. If the energy is applied or released abruptly, we get an oscillation in either case. The rebound that throws you into the top of the car, is the same kind of a thing as the electric rebound that sends out the wireless signal; and the same formula can be used in computing both phenomena, if we use the proper constants for the different cases.

When we make a tensile-strength test we are merely measuring the molecular attraction between molecules in the metal. The coefficient of elasticity, the tensile-strength, the density, are only bits of evidence as to the structure of the material and the nature of the forces holding the parts together. We cannot yet interpret all of this evidence, but we must learn to do so, so that not only our sciences may progress, but also our own automotive progress continue.

Car-Development Constituents

The car of 1922 differs from the car of 1909 only in changes in the proportions of the parts, and in the relationship of the forces and materials. The car of 1930 will differ from the car of today only in the same way. It is possible to point out some of the problems that will be solved completely, or in part, in the near future. These problems will be solved by the measurement of these relationships, and the determining of better proportions.

Take spring-suspensions and shock-absorbers, for example. When the wheel hits a bump in the road, the wheel starts to oscillate under the body and, if the oscillation persists, the body will take up motion as a result. Strike a bell, and the bell begins to vibrate, just as the wheel vibrates; and if we touch our finger to the bell the vibration stops. All the shock-absorber can do is the same thing, and the problem is to apply this resistance without interfering with the useful operation of the spring. If we have too much resistance in our wireless apparatus, it will not oscillate. In this case the resistance is injurious, as it interferes with the normal operation, but its action is exactly the same as the action of the shock-absorber.

Just recently we were shown a model of car made by a certain manufacturer; the engineer of this factory stated that this particular model was absolutely the best-riding car they had ever produced, and they could not tell why. The reason they could not tell was that they had not measured the fundamental relations that contribute to good riding.

What we need is more analysis of fundamentals and less invention. If we do not have a new inventor with a spring wheel come to the laboratory every week, we think something is wrong. If these inventors would analyze the situation, they would see that they were under an enormous handicap so far as competing with the pneumatic tire is concerned. When a pneumatic tire runs over a small bump in the road, the rim of the wheel and car proceed without being diverted from their path and without disturbance to the passenger. It is only necessary to move a small amount of rubber out of the path it would have followed, the energy involved is small, and the resulting shock is very small. When the solid rim of the spring wheel strikes the same bump, it is forced to deflect, and therefore accelerate a very much larger mass, resulting in the transfer of a much larger amount of

energy, and naturally a much greater shock to the vehicle and its passengers.

We shall see some real progress in riding qualities in the near future. Today the automobile salesman will tell you how the engine in his car will go 1000 or 1500 miles on a gallon of oil. When you buy the car you get an instruction book which tells you to drain the oil every 300 miles. You expect to discount what an automobile salesman tells you a little, but you do not expect to have to use so high a discount factor as this.

The gasoline we have today with an end-point of 440 deg. fahr. is very different from the fuel of the early automotive days. It really is not so much worse as a fuel than former gasolines, as it is different; and we must learn to use it efficiently. We can do this. We know enough about fuels, and methods of using them, to get very much better results out of the present-day fuels than were obtained with the fuels of 10 years ago. It is only necessary to build our knowledge into our new engines. Our problem is to do this in the simplest and most direct manner, and in such a way that the user will be least conscious of the change.

This brings us back to a point mentioned before, to which we must always give attention; the all-important question of providing an appeal to the user in our product. It is of no profit to an engineer and a manufacturer to produce a car that has more speed than any other, or will do more stunts than its competitors, if the public does not see at once a real gain in utility, in comfort to the user. If this gain is not evident, the public will go on buying cars of the older design, and be entirely right in doing so. It is sometimes better to go forward slowly, than to try to go too fast. Some of you may remember that the first single-cylinder cars had whipsockets on a dash that was no longer needed, for the arrangement of the car was very different than now. The public was used to seeing whipsockets on dashes, and bought vehicles so equipped with less hesitation than other types. This may be very extreme, but it illustrates a very human reaction toward change, and we must take account of this as we meet the problems of comfort and good riding, and the efficient use of oil and fuel.

Cost Considerations

I will close by pointing out once more that these problems must be solved at a minimum cost. All engineers realize that costs must be kept down and all engineers believe that they are taking account of costs. As a matter of fact, they are not giving enough thought to the most important cost of all, the so-called overhead cost. Many engineers are not studying it at all, not realizing that they are determining what the minimum overhead-cost of manufacturing is to be when they lay out their designs. Costs are divided into three factors; labor, material and overhead. If our designs contain details requiring special tooling or elaborate systems of inspection to secure the results desired, we have specified a high manufacturing overhead on our drawings, and our total costs will be high in spite of any effort we can make to reduce materials or the direct labor. When a piece is laid-out on the drawing-board, that is the time the method of manufacture should be worked out. For a given production-schedule, the tools required, the floor-space and the materials in process of manufacture can be determined, and what our capital investment is will be known. The losses in manufacture and the supervisory force are fixed by the number of operations and their difficulty. It may seem that the engineer is reaching out a little beyond his own field in attempting to analyze the overhead but, so long as the cost-accountants figure overhead as a fixed percentage, someone will have to get into the elements of this cost, if we are ever to reduce it; and we must reduce it. It is not reasonable to hold the engineer responsible for the overhead actually existing in many factories, but he does specify what the minimum overhead can be for a given production schedule, and he must accept the responsibility involved.

Automobile Finishing-Varnish

By L. Valentine Pulsifer[1]

Annual Meeting Paper

As the success or failure of the finish of an automobile depends largely on the finishing-varnish, a plea is made for more scientific analyses of the problems of automobile finishing and more care in selecting and applying a suitable varnish. The qualities to be desired in a finishing-varnish are divided into two classes: the shop qualities and the service qualities. The shop qualities include color, body or viscosity, working, flowing, setting, hardening, fulness and the safety of working. The service qualities, or those that enable the varnish to withstand the various conditions of use, include resistance to break-down under the chemical action of the actinic rays of sunlight, to the destructive action of moisture and the alkalis in mud and soap, to expansion and contraction, to vibration and to abrasion. The three most important factors in estimating the service-giving qualities of varnish are said to be elasticity, moisture-resistance and the film factor. Each of the various terms mentioned is carefully defined, analyzed and explained. Among the constants that must be determined, either for checking uniformity or for use as bases of tests, are the non-volatile content, which is the starting-point in the test for elasticity and in computing the film factor or thickness of the dried film; the ash, the flash-point, and the acid number. An empirical formula is derived by which the thickness of the dried film can be estimated with accuracy; and in a series of appendixes the details are given concerning tests for the drying, the safety of working, non-volatile content, ash, flash-point and acid number; the Kauri reduction test; and tests for moisture and alkali resistance.

LAST year before the Society of Automotive Engineers and the Automobile Body Builders Association I discussed the Manufacture and Application of Automobile Varnishes and Paints[2] and Some Problems in Automobile Finishing.[3] These two talks covered the basic principles of the manufacture of varnishes and paints and the fundamental engineering problems involved in the building of a successful automobile-finish. At the conclusion of the second of these talks I made the following statement:

> I hope the points and problems I have discussed will arouse a greater desire to study this particular field of automotive engineering, both on the part of the automotive industry and on the part of the paint and varnish industry. A scientific study of the problems involved, by as many qualified groups as possible, will yield ample dividends of satisfaction to all concerned.

This plea for cooperative effort along the lines suggested has roused considerable interest; and an attempt is being made to substitute knowledge for the hit-or-miss methods that in the past have been all too prevalent. With a desire to assist in establishing automobile finishing on sound engineering principles I shall take up the subject of automobile finishing-varnish in greater detail than time permitted in the two talks mentioned above.

Automobile Finishing-Varnish

Assuming that the undercoats of an automobile-painting system have been properly selected and applied and that the finished car will receive intelligent and proper care from its prospective owner, the success or failure of the finish will depend on the finishing-varnish.

The fact that the finish of many automobiles, even those of the highest grade, does not last so well as did the finish on the fine carriages of a generation or two ago, has led some persons to believe that the general quality of finishing-varnishes has deteriorated. Such a conclusion is the reverse of the truth, for it is possible today to obtain varnishes of far greater durability and much greater resistance to abuse than could be obtained from 25 to 50 years ago. The conclusion, however, is not unnatural if one does not consider that the finish on an automobile, even with normal use, undergoes a treatment that the carriage finish would never have received, and that thousands of automobiles are finished with varnishes that in the days of the carriage would hardly have been used even for quick cheap repair work. When speed, cheapness and the need of covering-up defects in the rubbing-coats are the compelling motives, finishing-varnishes sometimes are used that hardly exceed in durability a good elastic rubbing-varnish; but this practice usually is due to a lack of knowledge of the consequences involved. Even when these are not the determining factors, a finishing-varnish frequently is used that represents perhaps a scant 25 per cent of the maximum durability obtainable. Here, again, a lack of knowledge is involved, which, if it existed in the whole field of automotive engineering, would doom the automobile to hopeless failure. The use of a finishing-varnish with rubbing-varnish elasticity is about on a par with the use of cast iron for crankshafts, or white pine for spokes.

It is my purpose to describe the qualities required of a successful automobile finishing-varnish and the methods of determining whether these qualities exist in any given varnish.

Qualities to Be Desired

The most desirable qualities of an automobile finishing-varnish must be determined by the automotive and varnish industries jointly, for each understands best the limitations under which it has to operate. Compromises must be made between what is desirable and what is possible. This is true of varnish as well as of steel, leather and other automotive materials; and it is only when both parties desire to produce the best that the ultimate in automobile finishing can be obtained. The selection of the finishing-varnish best suited to a given car, a given production-schedule and a given method of application must be made after a combined study by the varnish manufacturer and the automobile builder.

To do this without great waste of both time and material, rapid methods of estimating must be used and the results of such estimating must be intelligently interpreted. The important qualities for convenience may be divided into two classes: (*a*) shop qualities and (*b*) service qualities; these will be taken up separately.

Shop Qualities

Shop qualities include color, body or viscosity, working, flowing, setting, hardening, fullness and the safety

[1] Chief chemist, Valentine & Co., New York City.

[2] See The Journal, January, 1922, p. 12.

[3] See *Automotive Manufacturer*, August, 1922, p. 26.

of working. To estimate them satisfactorily is easier than to estimate the service-qualities of an unknown varnish; and some of the qualities such as working, flowing, setting, hardening and the fullness of finish can be determined best in the shop itself under average shop conditions. By "working" is meant the possession of the proper working-properties for the method of application it is desired to use, whether by brush or by flow-coat. By "flowing" is meant the ability to flow-out properly without runs, sags, curtains or brush-marks, and yet to retain a suitable body of varnish on the finished surface. By "setting" is meant the ability to set slowly enough to allow the entire surface to become smooth and yet fast enough to prevent too long a flow, which sometimes permits the varnish to run over a molding or from an upper panel to a lower one. The "hardening" and "fullness" are estimated most easily on a body run through on the regular production-schedule, but the quality of hardness can also be determined satisfactorily by a laboratory test that duplicates shop drying conditions. The "safety of working," that is, the ability of the varnish to act properly under adverse shop conditions, is hardly an important factor in a modern automobile-plant. For drying and safety-of-working tests, see Appendix 1.

The two other shop qualities enumerated above, color and body or viscosity, are best estimated by using the Gardner-Holdt viscometer, an instrument developed in the research laboratory maintained in the City of Washington by the National Varnish Manufacturers Association. This is a bubble viscometer consisting of a series of 20 tubes standardized as to internal diameter and filled with standardized compounded petroleum oils. These oils vary in color and in viscosity; and each tube, marked *A, B, C, D,* and the like, contains an oil ½ bubble more heavily bodied than the preceding, and a shade darker in color. In 10-tube sets the variation between one tube and the next is one full bubble, which provides close enough gradation in both viscosity and color for the automotive laboratory. It takes a difference of more than one full bubble before the difference in viscosity will become noticeable under shop conditions. Each viscometer is provided with several extra standardized tubes in which are placed the varnishes to be tested.

The color determination should be made by placing the tube filled with the varnish and the different tubes of the viscometer, one at a time, close together, and looking through them by transmitted light, preferably daylight. If the color of the varnish matches the tube *D*, or is between *C* and *D*, its color can be recorded as "*D*" or "*C-D*." Other things being equal, the paler a varnish is the better it is, especially when the preservation of the purity of tone of light or brilliant colors is desired. It is convenient to use these same standard tubes of the Gardner-Holdt viscometer, which in color cover the range of clear automobile varnishes, for reading the color of a given varnish.

The viscosity is determined by holding the tube containing the varnish and one of the tubes of the viscometer exactly parallel in a vertical position and then rapidly reversing the tubes. When the tube of the set is found in which the rate of travel of the bubble is exactly the same as in the tube of varnish, the viscosity of the varnish is read as, say, F-1.40 poises, the poises, or measure of absolute viscosity, having been determined for the different tubes of the viscometer. This test should be made carefully to avoid any differences of temperature in the tubes of varnish or oil and the temperature preferably should not vary more than 1 deg. above or below 77 deg. fahr.

As different methods of application and varying shop conditions and temperatures demand varnishes of different viscosities, the method and the apparatus outlined above are the best and most practical that have been devised.

The statement that some shop qualities can best be tested in the shop itself should be qualified by saying that if the tests are so made they should be under adequate technical supervision and carefully checked by the engineering department to assure standardized conditions and authentic records. The subject of service qualities falls almost entirely within the laboratory.

Service Qualities

By service qualities are meant the qualities that determine the ability of a varnish to give service, that is, to stand up under the numerous varying conditions of automobile use. Before deciding what these qualities are it is necessary to understand the causes of the final break-down that comes eventually to all varnishes. The most important is the chemical action of the sun's rays, that is, the actinic rays of sunlight. These slowly break-down the vegetable compounds in the dried film of varnish and promote progressive oxidation or "rotting," thereby causing a gradual loss of elasticity. When the elasticity of the film is reduced below that which is necessary to withstand the expansion and contraction of the surface underneath, and the vibration, small cracks appear and the final break-down approaches.

The importance of the chemical rays in sunlight, as the prime factor in the destruction of finishing-varnish, is evident when one observes the perishing of decks and cowls long before the more nearly vertical panels of the body. The surface that gets the sun's rays most nearly perpendicularly will perish first; in fact, on test exposure-panels, a panel exposed at an angle of 45 deg. from the vertical facing south will perish in about one-half the time of an exactly similar panel exposed vertically, and a panel exposed vertically facing north will last approximately twice as long as the one exposed vertically facing south. The effect of the angle of exposure is not always understood, as is shown by the fact that the hoods of automobiles are frequently finished with a varnish less durable than that used on the bodies.

On the top panels of most hoods the angle is about the worst possible, the expansion and contraction owing to changes of temperature being more severe and the vibration very much worse than anywhere else on the car.

A factor contributing largely to this gradual break-down is moisture or moisture plus alkali, in the form of soap or of mud. The presence of moisture in the varnish-film aids the chemical action of the sun's rays in the final break-down of the varnish. The destructive action of alkalis such as mud and soap in connection with varnish is, of course, well known. Abrasion also is a contributing cause of the perishing of the coat of finishing-varnish, for the scratches in the surface caused by careless washing or the use of dry washes or polishes when dust or dried mud is on the car, develop eventually into cracks.

To sum up the causes of the deterioration and eventual destruction of the finishing-varnish, we have, first and most important, the chemical action of sunlight, aided by moisture, alkalis, expansion and contraction, vibration and abrasion.

It is clear that to postpone this final break-down a varnish should possess as great an initial elasticity, as high a resistance to the destructive chemical effect of moisture and as thick a dried film as are permitted by the method of application and the time-schedule.

Estimation of Service Qualities

After the automotive engineer has decided on the type of finishing-varnish he wishes to use, he should have the means at his disposal first for finding and then for check-testing the deliveries of the material selected. A lack of such laboratory means would spell chaos if it extended over the whole list of automotive materials, yet many otherwise well organized plants lack the laboratory means for testing and estimating varnish.

The varnish industry as a whole is perhaps as responsible for this lack as is the automotive industry, although, as already mentioned, the National Varnish Manufacturers' Association maintains in the City of Washington a research laboratory that is devoted to the production problems involved in varnish manufacture.

The research laboratory of the company that I represent has striven earnestly to perfect and to standardize the methods of estimating the qualities desirable in a varnish; and some of the methods have been adopted by Government laboratories and by the laboratories of certain railroad, automotive and industrial units. The three most important factors in estimating the service-giving qualities of varnish are elasticity, moisture-resistance and the film factor.

In beginning the examination of a varnish it is useful to determine certain constants that are used in checking uniformity or as bases for other tests. The most important is the non-volatile content, as this is used as a starting-point in the test of elasticity and as one of the necessary elements in computing the film factor or the approximate thickness of the dried film. Next, chiefly for checking purposes, is the ash, which, if it does not exceed 1 per cent, is not important; the flash-point, which, to assure proper working qualities and low fire-hazard, should not be below 105 deg. fahr.; and the acid number, which is unimportant except as a checking figure. The proper methods for determining non-volatile content, ash, flash-point and acid number will be found in Appendix 2.

Elasticity

Elasticity is the most important factor in determining the service-durability of a finishing-varnish and, other things being equal, the comparative durability of a series of varnishes follows exactly their comparative elasticity. This factor can be estimated in the laboratory by the so-called Kauri reduction-test for elasticity. This test was developed by me several years ago after a series of experiments made with a view to perfecting a laboratory method for rapidly and accurately estimating the elasticity factor. It was adopted by the Government during the war for airplane use and has since appeared in numerous specifications, replacing the former slow and unsatisfactory panel-exposure test.

The test is based on the fact that, if two varnishes are equal in other respects, their elasticity will vary with the gum-oil ratio; in other words, the higher the fixed-oil content in terms of the gum content, the greater will be the elasticity. In making the test various amounts of a standardized gum in solution in redistilled spirits of turpentine are added to the varnish. The varnish is then put through a forced drying process on a standardized tin-plate and the plate thus coated is bent rapidly over a rod of fixed diameter. The amount of gum solution necessary to bring the varnish to the cracking-point under this procedure forms a measure of its elasticity, that is, the greater the amount of gum solution necessary, the higher is the elasticity. The elasticity factor is read and recorded in terms of the percentage of gum solution that it is necessary to add to the varnish to bring it to the cracking-point, say, 20, 60 or 120, as the case may be. This test determines only the elasticity factor of the varnish and not the original gum-oil ratio, for the kinds of gum and oil used, the kind and amount of drier and the heat-treatment of the varnish during its manufacture all influence the elasticity factor of the finished product. The fact that it is possible to have two varnishes of the same gum-oil ratio that will differ in elasticity by more than 100 per cent shows why it is easier to estimate the quality of a varnish by physical tests than by analyses of the components, even were it possible to make such analyses with accuracy.

The range of percentage of the gum solution that exterior varnishes will stand on the Kauri reduction-test is from 0 to 200, the 0 per cent being on the border-line between the most elastic of the rubbing-varnishes and the least elastic of the finishing-varnishes, and the 200 per cent representing the maximum elasticity of a fixed vegetable-oil varnish that contains no gum whatever. Full directions for determining the elasticity factor of a finishing-varnish are given in Appendix 3.

Resistance to Moisture and Alkalis

Varnish is affected by moisture in two ways, physically and chemically, and by alkalis, for both the gums, or resins, and the vegetable oils used in making it, are saponifiable in varying degree. The degree in which varnish is affected by moisture and alkalis can be varied within very wide limits, by both the composition and the heat-treatment of the varnish during its manufacture. For purposes of comparison, the rate at which different varnishes absorb moisture can be determined with sufficient accuracy by observing the rate at which they turn white or opaque when they are immersed in either hot or cold water. Susceptibility to chemical injury by water can be measured by ascertaining how long they must be subjected to the action of water, either hot or cold, before they become permanently whitened, for permanent whitening indicates a chemical change in the structure of the varnish. Comparative resistance to the destructive action of alkalis can be determined by immersing the varnishes in a standard soap-solution for short periods of time, the action of the alkalis on the gums and oils being indicated by loss of lustre and whitening.

It is necessary to make these determinations because they have an important bearing on the service-giving qualities of the varnish. In this connection it should be remembered that resistance to both water and alkalis is of greater importance in the case of a varnish that is to be used on the hood, fenders, wheels and axles than of a varnish that is to be used on the body. In a body-varnish, a resistance to these two elements as high as can be attained without sacrificing the necessary elasticity and freedom of working and flowing is desirable, and, other things being equal, the body-varnish that resists moisture and alkalis most effectually is the best choice. A description of the methods for making tests for resistance to moisture and alkalis is given in Appendix 4.

Film Factor

By the film factor is meant the normal thickness of the dried film. The durability of a finishing-varnish varies almost directly with the thickness of the film, provided, of course, the film is not too thick to harden through properly. In the case of undercoats a thick film is to be avoided, but in the final coat the thicker the better, provided, as said before, it is not too thick to dry and to harden properly. Actual measurements of film thickness involve considerable trouble and are difficult to make

accurately. But a sufficiently accurate calculation can be made from data used in the other tests. These data are the viscosity of the varnish, in poises, and the non-volatile content, in per cent. By using the following equation the normal thickness of the dried film can be estimated with surprising accuracy, as has been demonstrated in our laboratory by a large number of check-tests.

$$F = \tfrac{1}{2}(10V - N)$$

where

F = the film factor in microns
N = the percentage of the non-volatile content
V = the viscosity in poises

For example, a body-finishing varnish having a viscosity of 1.40 poises and a non-volatile content of 64 per cent will figure as follows:

$$F = \tfrac{1}{2}[(10 \times 1.40) + 64]$$
$$= 39$$

A 2-ft.-square glass panel finished with a normal coat of this particular varnish and measured with the aid of a powerful microscope gave average readings of exactly 39 microns.

This determination of the film factor completes the data on which the service-durability of the varnish is to be estimated; next comes the assembling and the intelligent appraising of the data. Perhaps the easiest way to explain the methods used is to take four finishing-varnishes, *A*, *B*, *C* and *D*, which are in use in quantity production and on which the elasticity, the moisture resistance and the film factor have been determined, and to rate them according to their estimated service-durability. By "durability" is meant the ultimate protection afforded the paint structure on an automobile body under actual service conditions, and not the first signs of checking or cracking looked for on a laboratory exposure-panel. The four varnishes selected represent, approximately, the minimum and the maximum limits in color, viscosity, non-volatile content, film factor, moisture resistance, elasticity and service-durability of the varnishes in current use for finishing automobile bodies.

The successful comparative rating of varnishes on these data requires careful consideration coupled with experience in varnish testing and research. This is especially true of the resistance to moisture and alkalis. If, however, on the basis of the water and alkali tests outlined above and detailed in Appendix 4, the varnishes are given moisture-resistance factors, a reasonable rating will result for average service conditions. A varnish that stands these tests poorly will receive a 0 rating; fair, 10; good, 20; and very good, 50.

To determine the comparative service-durability ratings of the four varnishes, we add together the figures obtained for each in our tests for elasticity, moisture resistance and film factor. This gives the results presented in Table 1.

TABLE 1—SERVICE-DURABILITY RATINGS OF FOUR FINISHING-VARNISHES

Finishing-Varnishes	*A*	*B*	*C*	*D*
Elasticity Factor	10	60	90	160
Moisture Resistance	0	10	20	50
Film Factor	35	47	52	36
Service-Durability Rating	45	117	162	246

The film factors for these different varnishes were arrived at by calculation in the formula given above and were based on the data contained in Table 2.

Based on the above rating, varnish *B* would have a service-durability approximately 150 per cent greater than that of varnish *A*; varnish *C* would exceed the service-durability of *A* by about 260 per cent and of *B* by about 40 per cent; and varnish *C* would show a service-durability that is more than 400 per cent greater than that of *A*, more than 100 per cent greater than that of *B* and approximately 50 per cent greater than that of *C*. Expressed in length of life under service conditions, presupposing that the undercoats had been properly applied and that the finish of the car had received intelligent care, varnish *A* would give about 4 months of service, varnish *B* would last about 1 year, varnish *C* would survive almost 1½ years of service and varnish *D* would last 2 years, before needing renewal.

TABLE 2—DATA ON WHICH THE FILM-FACTOR VALUES IN TABLE 1 WERE BASED

Finishing-Varnishes	Viscosity, Poises	Non-Volatile Content, Per Cent
A	1.25	58.75
B	3.20	63.75
C	3.20	73.00
D	1.65	56.00

The fact that varnishes vary in durability by as much as 500 per cent may prove surprising. The facts, methods and conclusions I have presented form an outline that the automotive engineer can expand or condense according to his needs.

The information given and the suggestions made may be completely and concisely put into three words: *Know Your Varnish!*

APPENDIX 1

Drying and Safety of Working Tests

To test the drying and hardening of the varnish in the laboratory the following standard method will be found satisfactory: Pour the varnish to be tested on a bright tin-panel, 3 x 5 in. in size, that has been carefully cleaned with benzol, and stand the panel in a nearly vertical position in a well ventilated room kept at the same temperature as the shop in which the varnish is to be used, say 70 to 80 deg. fahr. The panel must not be placed in the direct rays of the sun. From time to time test the film by touching it lightly with the finger at points not less than 1 in. from the edges of the film. The varnish is considered to have dried to touch when gentle pressure shows a tacky condition but no varnish adheres to the finger. The varnish is considered to have dried hard when the pressure that can be exerted between thumb and finger does not move the film or leave a permanent mark after the spot has been lightly polished.

An over-sensitiveness to adverse shop conditions can be determined by the following simple test: Pour an excess of the varnish on a small 3x5-in. tin-panel that has been carefully cleaned with benzol, and immediately place the panel in the direct draft of a small 8 to 10-in. electric-fan, running at full speed. The panel should be placed in a nearly vertical position approximately 2 ft. from the fan and at an angle of 45 deg. to the line of the air-current. Allow the panel to remain in this position 5 hr.; remove and allow the varnish to harden overnight. The varnish should show no dulling, enameling, crow-footing or frosting. This test should be made under shop conditions that are normal as to ventilation and temperature.

APPENDIX 2

Laboratory Determinations

NON-VOLATILE CONTENT

Place a portion of the sample in a stoppered bottle or a weighing pipette. Weigh the container and the sample. Transfer about 1.5 grams of the sample to a weighed

flat-bottomed metal dish about 8 cm. in diameter, a friction-top can plug. Weigh the container again and by the difference calculate the exact weight of the portion of the sample transferred to the weighed dish. Heat the dish and contents in an oven maintained at 105 to 110 deg. cent. (221 to 230 deg. fahr.) for 3 hr. Cool and weigh. From the weight of the residue left in the dish and the weight of the sample taken, calculate the percentage of non-volatile residue.

ASH

Determine the ash in 10 grams by ignition, in a quartz or a porcelain dish, carrying out the determination at a low heat, preferably in the muffle. If a muffle is not available, the thinner should first be driven off on a hot plate or in an air-bath before direct ignition. Particular care must be taken not to over-hasten the procedure during ignition, as a reduction of the lead drier salts would invariably follow.

FLASH-POINT

The open-cup method may be used, as described in the tentative standard of the American Society for Testing Materials, No. D92-21T, or else the closed-cup method, according to Standard No. D56-21 of the American Society for Testing Materials.

ACID NUMBER

Weigh 10 grams of varnish in a 200-cc. Erlenmeyer flask, add 50 cc. of neutral alcohol, connect with a reflux air-condenser and heat in a steam-bath for ½ hr. Remove from the bath, cool, add phenolphthalein and titrate the free acid with fifth-normal sodium hydroxide. Calculate the acid number, that is, the milligrams of potassium hydroxide to 1 gram of varnish.

APPENDIX 3

The Kauri Reduction Test

Preparation of the "Run" Kauri.—Arrange a distillation-flask, a water-cooled condenser and a tared receiver on a balance. Place in the flask about one-third of its volumetric capacity of clear, bright hard pieces of Kauri gum, broken to pea-size. Carefully melt and distill, until 25 per cent by weight of the gum is collected in the tared receiver. At the end of the distillation, the thermometer in the distillation-flask, with the bulb at the line of the discharging-point of the flask, should register about 600 deg. fahr. Pour the residue into a clean pan and, when cold, break into small pieces

Preparation of Standard "Run" Kauri Solution.—In a carefully tared beaker place a quantity of the small broken pieces of the "run" Kauri with twice its weight of freshly redistilled spirits of turpentine, using only the portion that distills over between 308 and 338 deg. fahr. Dissolve by heating to a temperature of about 300 deg. fahr. and bring back to correct weight when cold by the addition of the amount of redistilled spirits of turpentine necessary to replace the loss by evaporation during the dissolving of the gum

Reduction of the Varnish.—First, carefully determine the non-volatile content of the varnish under test according to the method outlined in Appendix 2. Then take 100 grams of the varnish and add to it an amount of the standard run Kauri solution equivalent to 50 per cent by weight of the non-volatile matter in the varnish. Mix the varnish and the solution thoroughly. For the sake of simplicity the amount of varnish to be used is given as 100 grams, whereas 25 grams is sufficient, and taking the smaller amount will conserve the supply both of the sample and of the standard run Kauri solution

Flow.—Place a coat of the varnish thus reduced on a standard 3 x 5-in. tinned panel, carefully cleaned with benzol, and allow it to dry in a nearly vertical position at room temperature for 1 hr. Next place the panel in a horizontal position in a properly ventilated oven and bake it for 5 hr. at from 96 to 100 deg. cent. (205 to 212 deg. fahr.). Remove the panel and allow it to cool at room temperature, preferably 75 deg. fahr., for 1 hr.

Elasticity Test.—Place the panel with the varnish side uppermost over a 2-mm. (⅛-in.) rod, held firmly by suitable supports at a point equally distant from the top and the bottom edges of the panel, and bend the panel double rapidly. The varnish should show no cracking at the point of bending. For accurate results the bending of the panel should always be done at 75 deg. fahr., for lowering the temperature will decrease the percentage of reduction that the varnish will stand without cracking; while raising the temperature will increase the reduction.

If the varnish, when tested as outlined in the preceding paragraph, cracks with the 50-per cent reduction specified, make up additional samples reduced with lesser amounts of the standard Kauri solution until a point is reached where it does not crack. If, on the other hand, the varnish does not crack when reduced 50 per cent, prepare other samples reduced with larger amounts of the standard Kauri solution, until the cracking-point on subsequent baking and bending is determined

The panels required for this test are of bright tin, 3 x 5 in., and approximately 0.278 to 0.297 mm. (0.0109 to 0.0117 in.) thick. The weight of the metal per standard base box, 112 sheets 14 x 20-in., Nos. 31 and 30½, United States standard plate gage, is 90 to 100 lb. They should be thoroughly cleaned with benzol immediately before using

This test, carefully followed out, will enable the varnish-testing laboratory to rate the comparative elasticity of a number of unknown varnishes within 2 working days and with greater accuracy than is possible by the panel weather-exposure test, which requires several months. It can also be used for checking the elasticity of deliveries against previous standards. As the elasticity of a varnish is the chief factor in determining its durability, the value of this test, in both time-saving and accuracy, over that of former methods is very great.

APPENDIX 4

Moisture and Alkali-Resistance Tests

For determining the moisture and alkali resistance of a varnish the following method will be found simple and efficient. For the tests use bright tin-panels, 3x5 in., carefully cleaned with benzol before using. The same panels specified for the Kauri reduction test may be used.

Pour the varnish on three of the panels, place them in a well ventilated room at shop temperature, preferably from 70 to 80 deg. fahr., out of direct sunlight, and allow them to dry for 48 hr. Place one of the panels in a beaker containing about 2½ in. of distilled water, immersing the end that was uppermost during the drying period, and leave it in the water at room temperature for 18 hr. Remove it and allow it to dry at room temperature for 2 hr. At the end of this period the varnish should show no permanent whitening and not more than a slight dulling. Place the second panel in a beaker containing about 2½ in. of boiling distilled water, immersing the end that

was uppermost during the drying period, and allow it to remain in the boiling water for 15 min. Remove it and allow it to dry at room temperature for 2 hr. At the end of this period the varnish should show no permanent whitening and not more than a slight dulling. If the finishing-varnish does not pass these tests it can be rated as poor on moisture-resistance. In getting the comparative moisture-resistance of a number of varnishes it may be necessary to repeat the tests one or more times. An automobile finishing-varnish need not have the high moisture-resistance demanded in a spar-varnish, but, other features being equal, the finishing-varnish showing the highest degree of moisture-resistance will remain bright and afford protection for the longest time under the conditions of automobile use.

The third panel mentioned above may be used for testing the resistance to alkalis; in this test a standard soap-solution consisting of ½ oz. of Ivory soap dissolved in 1 gal. of distilled water is used. Place the panel in a beaker containing about 2½ in. of the standard soap-solution heated to and maintained at a temperature of 120 deg. fahr. Leave the panel in the hot solution 10 min., remove it and immediately rinse it thoroughly in clear cold tap water, and allow it to dry at room temperature for 1 hr. At the end of this period the varnish should show no whitening and not more than a slight dulling. A finishing-varnish failing to pass this test should be rated poor on alkali-resistance. In getting the comparative resistance to alkali of a number of varnishes this test may be repeated one or more times, using fresh soap-solution each time. While all oil-varnishes will finally be destroyed by the action of alkali, other features being equal, the finishing-varnish showing the highest degree of resistance to its action will remain bright and afford protection for the longest time under the conditions of automobile use.

A higher resistance to the action of moisture and alkali should be required of a finishing-varnish for use on hoods, fenders, wheels and underparts than is required for body use.

The Needless Hardwood Lumber Waste

By Frederick F. Murray[1]

Annual Meeting Paper *Illustrated with* Drawings

THE production of hardwood lumber has not kept pace with factory development, particularly that which has taken place in the automotive field. Some persons maintain that lumber is not susceptible to "development"; but all sorts and conditions of hardwood lumber are produced from the same tree and only a part is suitable for automotive construction. Some portions of the tree are far more suitable for furniture manufacture, while others are peculiarly adapted for use in parquetry and in building trim. Development, therefore, consists of properly differentiating the various kinds of material that come from the hardwood log so that the various industries may have at their disposal boards that have been properly classified. As the present system of grading has been in effect substantially without change for over a quarter of a century, years before the automobile came into general use, the grades originally established have little bearing upon automotive utility. Revised specifications for grading that would determine the major requirements, which in themselves include the secondary requirements, would on the whole obviate much of the waste that occurs under the present method.

Designating the grade in terms of the cut-up value would provide a real and much needed simplification and avoid many existing inconsistencies. It would tend to discourage manipulation, the substitution of inferior grades and other irregular practices, that though reasonably infrequent are detrimental to the industry. Hardwood standardization is a component part of a general movement that involves all species of lumber, both softwood and hardwood, that is crystallizing in an organization recently instituted in the city of Washington and known as the Central Committee on Lumber Standards. This committee is endeavoring to produce a new and scientific grading-schedule that by common accord will establish a lasting instrument to be entitled the American Lumber Standards.

THE increasing difficulty experienced by the automotive engineer in securing the kinds, qualities and quantities of hardwood lumber necessary for the automotive body is a pressing subject of complaint. It has been asserted that the woods of today are not as good as they were 10 years ago, and that with the excessive proportion of waste compared with the original shipment of lumber the scientific development of factory practice in increasing production, cutting costs and eliminating unnecessary waste has become a difficult task.

The very apparent uncertainty as to the yield that a shipment of hardwood lumber will give in terms of the fabricated parts, and, in general, the inability to figure lumber as an exact factory raw material, are leading the factory user to believe that hardwoods are becoming too expensive and too much of a gamble. One of the primary sources of the belief that the price of hardwoods is making their use prohibitive lies in the fact that practically all the consuming interests consider the top grades of hardwood essential for their purposes, with the result that there are not enough top-grade materials to go round.

Estimated 3 Per Cent of Boards Produced Is "Clear"

It should be noted at the outset that only about 3 per cent of the boards produced from the hardwood log is "clear," that is, free from any form of defect, such as discoloration, worm holes, knots and other characteristic blemishes that affect the appearance and strength of the boards. The top grade of hardwoods, of course, includes not only all this clear material, but also lumber with defects of a specified character and number, the number depending upon the surface measure of the board.

Although the quality of hardwood lumber is declining somewhat, an actual scarcity will not be felt acutely for many years. If corrective measures are taken to utilize present-day production better, and if increased attention is given to forest conservation and reforestation, it can logically be expected that a timber famine will be projected far into the future, many generations hence.

The use of wood in automobile body construction during the past 15 years has progressed, strange as it may seem, both forward and backward at the same time. In the individual body, its use has been on the decline, but the total consumption has gained remarkably, owing to the tremendous increase in the production of motor vehicles.

Not long ago the all-wood body, featuring the use of wide poplar, was considered to be the most desirable construction for the passenger-car body. Aluminum sheets then supplanted wood for the panels, and now in the less expensive cars we find sheet iron or sheet steel, the skeleton of wood, however, being retained. The latest development, the "all-steel" body, seeks to replace this wood framing, and is significant in that it seems to indicate that the use of hardwood has not kept pace with other developments in the automotive field; otherwise the qualities that are so desirable and found in wood alone, would not be replaced.

Hardwoods Not Yet "Developed" to Provide Full Utilization Value

Briefly, the situation is that at present the consumer in the automotive as well as in other fields, is not getting the utilization value from a shipment of lumber that he is getting with shipments of other raw materials for factory use.

In this connection it should be pointed out that there has been substantially no change in the wood itself, except in its abundance. Ash is still ash and maple maple; and, in fact, the same raw material is served to the industry that has been served for many years and is obtainable under the same specifications. This is not cited as a recommendation, or to call forth approbation, but rather to carry the point that the changes have not taken place in the manufacture and distribution of hardwood

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lumber that are needed to place hardwood lumber in a competitive market with substitutes. And this is a fact that "substitutes" are making capital of.

In opposition to such an argument it has been pointed out that hardwood lumber is "just lumber" and, consequently, there is no opportunity for development. This theory is erroneous in that there are all kinds and conditions of hardwood lumber. There is great opportunity for segregation to provide each consuming industry with the portion of the tree that it can use to the best advantage with a minimum of waste. Anyone familiar with the present conditions in the hardwood lumber business, from either the producer's or consumer's standpoint, readily appreciates that very little has been done to perfect the utilization of hardwoods from the tree through the factory. Without some thought the possibility of improvement in this direction is not directly apparent.

Interests of Consumer and Producer Bound Together

It should be emphasized in outlining a program to improve conditions in the hardwood business, from both the consumer's and the producer's standpoints, that any development which the producer might propose would immediately be felt by the consumer, and, likewise, that any proposition which the consumer might promulgate would affect the producer. Is it not apparent then that these two elements in the trade must go hand-in-hand in order that the interests of both may be served to their mutual advantage? On such a foundation alone can a satisfactory adjustment be made.

It has been proposed by various organizations of consumers that the producer suggest specific points for the consumer to consider and, likewise, the producer has asked the consumer to suggest points wherein an advantage might be gained. In the first case, the producer is assumed to be endeavoring to force an issue; in the second case the usual attitude is that the consumer is endeavoring to work a hardship on the producer. Unless these two elements are definitely coordinated and a thorough study is made of the possibilities and limitations of each, there can be no complete accord and elements of distrust are likely to arise.

When one endeavors to supplant a grading vehicle, originated over a quarter of a century ago and sustained practically without change since that time, a fundamental necessity is that the purpose be clearly understood from the beginning, and each phase of the development likewise, so that there shall be no dissenting voice when the ultimate end is reached.

Summarizing, it should be emphasized particularly that standardization and waste elimination in the hardwood industry from the tree through the factory is a problem common to the producer and the consumer and to these two elements alone; and that betterments cannot be instituted without a careful canvass of conditions, so that such revisions of existing practice as may be developed will be thoroughly understood as to motive and purpose, and be accepted with the knowledge that they are for the best.

Present Grades Inadequate, Obsolete and Wasteful

There is ample reason for the statement that present grades of lumber are inadequate and that the specifications long since have become obsolete. During recent decades great consuming industries have been conceived and developed, typical among which is the automotive industry that now stands second in the consumption of hardwood lumber, being surpassed only by the furniture industries. Is there not some question whether the automotive industry can be served adequately by specifications that were developed before its existence and obviously without regard to automotive utility?

A grading structure for any raw material or commodity used in factory practice can be adequate only if the purposes for which it is to be used are thoroughly considered in the grades. It is vital to the automotive industry that it should be recognized as the second largest consumer and that such provision should be made in a grading program that the parts of the hardwood tree suitable for automotive manufacture shall be made available to the industry, and not be scattered in various directions.

It is a fact, well known to every consumer, that in the existing grades there is no guarantee that any industry can realize a certain minimum yield in the factory from any one grade; and until a grading structure shall have been developed that will specify the maximum amount of waste to be allowed in fabricating to certain sizes, no consumer can gage his factory operation with any degree of certainty, and the abnormally large waste, often specified as high as 60 per cent, will continue.

Summarizing, the first inadequacy of the present grade structure with respect to the automotive industry and to every factory cut-up industry using hardwoods, is that the grades have been made without regard to the specific requirements of the factory. While admittedly each individual requirement cannot be served in an isolated way, specifying the determining requirements, which in themselves include the secondary requirements, would as a whole result in much less waste than prevails under the present method of grading.

Destructive criticism without a constructive building program is worse than useless. In brief it may be said that the answer lies in determining in a thorough and comprehensive way the cut-up requirements of the major branches of the consuming industries, basing the grade structure upon suitable composites of these utilities, and defining the specifications in terms of the cut-up requirements, thus standardizing hardwoods as a commodity with a guaranteed yield that can be determined by a straightforward yardstick method.

Reason for Obsolescence of Present Grade-Basis

The present grade structure, though wholly inadequate as a scientific grading vehicle, was developed with the most painstaking care over a period of years that marked no change in the basis plan. At the beginning the use of hardwoods was very much restricted and hardwood products went largely to the furniture and wagon trades. Today there is a very high degree of specialization in the furniture field. For example, the chair industry has clearly defined itself. There is the table industry and another specializing in bedroom suites. Progress has been made in placing the general furniture factory in the discard in favor of the shop that specializes in a limited line, but this has not contributed to a better utilization of lumber, inasmuch as the present grade-basis was in existence at the time the general furniture factory predominated. The specializing interests are now seeking a specific yield from each shipment of lumber, and it is a matter of common observation that the present grades cannot serve adequately in this particular. All the shops have departed from the "carpenter-shop" method and become production factories where a severe burden is entailed by any element that impedes straightforward progress. It is obvious that with the cut-up orders limited because of the manufacture of specialized lines, there is not the opportunity on the present

FIG. 1—PRACTICAL EXAMPLES OF BOARDS THAT ARE CLASSED AS NO. 1 COMMON HARDWOOD

grade-basis to utilize the entire board, as might be the case in carpenter-shop operation.

As a specific example, consider the top grade of hardwoods under the present grading structure, a classification known as "firsts and seconds" grade. The grade definition defines the poorest board that may properly be classed within the grade and limits it in terms of enumerated defects, such as a 1¼-in. knot.

In 16-ft. lengths a board 6 in. wide can make the top grade with two defects; a board 9 in. wide, three defects; 12 in. wide, four defects; 15 in. wide, five defects; absolutely without regard to where the defects may appear in the board or to their relative positions.

GRADING BY "ENUMERATED DEFECTS" WRONG PRINCIPLE

Obviously, the cut-up value of the board is vitally affected by the relative positions of the defects, as possibly these may combine so as to render the board next to useless from the standpoint of the waste entailed in cutting to certain requirements. From this a simple and positive statement can be made and, indeed, such a statement crystallizes the thought into specific terms as to the inadequacy of the present grades. Bearing in mind the example just given and illustrated diagrammatically in Fig. 1, the following should be clear: *No grade, be it a top grade, an intermediate grade or the lowest grade, should be determined by the enumerated allowable defects without regard to the location of those defects in the board.*

Considering an intermediate grade, "No. 1 Common" may be briefly reviewed. In this grade "clear face cuttings" are specified, which must be not less than 4 in. wide by 2 ft. long, or 3 in. wide by 3 ft. long, neither being given the preference, thus making it impossible to figure a minimum for the larger-size cutting. There are factory interests that from the nature of their manufacturing should use a relatively low-grade lumber, but in such lumber they must be assured of certain cuttings. If these interests require the 4-in.-wide cutting, this grade of No. 1 Common, just defined, would give them absolutely no assurance of a minimum percentage of 4-in. cuttings. The present grade of No. 1 Common allows the 4-in. cutting, but places no restriction that cuttings shall be wider than 3 in. in order that the board shall make the grade. The grade specifies "clear face," but some utilities require the opposite faces to be clear and others all four faces clear.

For the reason that grading on the present basis does not take cognizance of such factors, that are vitally important from the utilization standpoint, there is the ever-increasing tendency to buy top-grade lumber. This, of course, includes all the clear lumber produced from the tree, so the purchaser of this grade knows that he is getting the best lumber produced and, accordingly, that he stands a better chance of covering his cutting requirements.

The next step in the process is for the consumer to feel the increasing cost of this top-grade material and to come to the conclusion that the cost is too great. He will then cast about for a substitute for hardwoods. Hardwoods have certain inherent qualities that are possessed by no other raw material. These qualities are fully tested and a substitution of other qualities cannot produce the same finished article. Ultimately, therefore, the burden is passed on to the public. By the same process, the producer of hardwoods finds a ready sale for the high-grade lumber from the log, but is burdened with as much as from 40 to 50 per cent of low-grade material. The latter is very difficult to sell and is sometimes impossible to move, so that through exposure over a period of many years at the sawmill it may become next to worthless.

ECONOMIC SEASON FOR HIGH PRICE OF HARDWOODS

In the economic analysis of this condition, the top grades under the present basis must carry the burden of the low grades; otherwise the hardwood producing plant could not function. And it must be borne in mind that the production of low-grade hardwoods entails the same proportionate expense that is incurred in the production of top-grade.

Under the circumstances just cited and because of the lessening of the supply of high-grade hardwoods in our forests, the price-trend of this material must be upward; there can be no alternative. Corrective measures are therefore in order and are urgently needed. The pro-

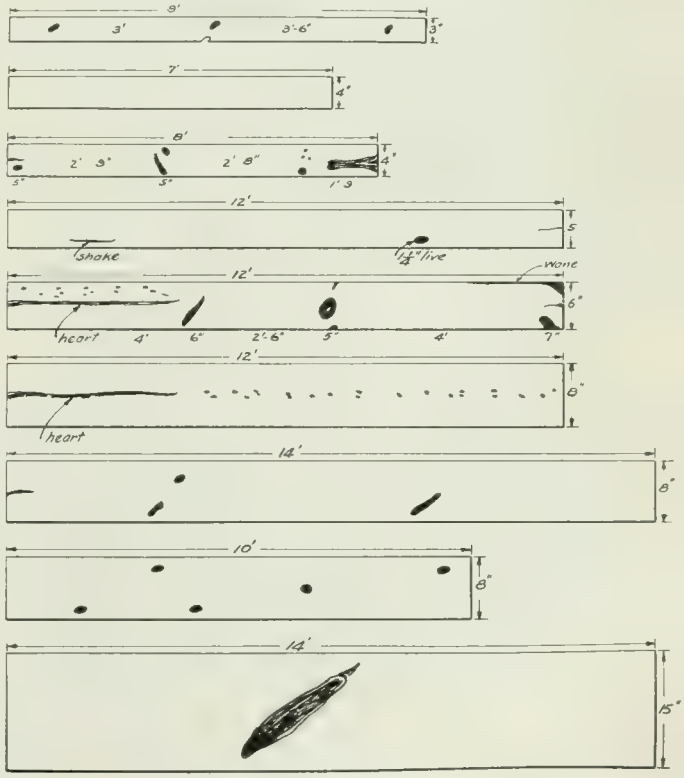

FIG. 2—WIDELY VARYING CLASSES OF BOARDS ALL FALL IN THE NO. 1 COMMON GROUP

ducer of hardwoods senses the situation and seeks relief on the same fundamental ground that the consumer complains of in his inability to realize from a shipment of lumber in the face of oppressive waste.

The drawing reproduced in Fig. 1 shows the boards that are graded as either No. 1 or No. 2 Common and that in Fig. 2 illustrates the wide range in types or classes of board admitted to the one grade of No. 1 Common. A study of these will indicate clearly the economic deficiency of a grade structure that places all these boards under a like classification. Fig. 2 answers very clearly the query as to why today two shipments of No. 1 Common hardwoods on identical orders may give factory yields varying up to 30 per cent.

It should be clear that the deficiency of the present system lies in the failure to classify the board on the yield basis. In the present scheme the entire board is the grading unit. In factory lumber the board is to be cut up; hence it is fundamentally wrong to base the grade upon the entire board as a unit. The factory cut-up size should be the grading unit and the manner in which factory sizes are contained in the board should determine the grade, for on that basis is the value of the board determined for factory purposes. *It is the usable material in the board that determines its value to the factory and, accordingly, this is the only basis upon which a grading structure should be built.*

Corrective Effort to be Applied in Safe and Sane Way

The present grades are not based upon this simple and unassailable fact. However inadequate the present structure may be, it cannot be abandoned until a new vehicle is available and that vehicle has been tested and found to be thoroughly true. It is in the development of this new structure that the Hardwood Manufacturers' Institute, an association restricted in membership to hardwood producers and representing over 35 per cent of all the hardwood lumber produced in this Country, seeks to engage the interest and support of the hardwood consumer to expedite the developing of maximum service in accordance with the consumer's need. Within the limitations of manufacture this represents the maximum service to the producer also.

To achieve the desired end, a sound foundation must be laid and must consist of a thorough knowledge of the requirements of all the major consuming industries. This knowledge is obtainable only by an engineering search and a thorough canvass in cooperation with the consumer.

Great Opportunity for Simplification

Aside from a great saving in eliminating the unnecessary waste and such would be certain in developing a new grade structure on the basis of factory yield, great good would come from simplifying the grade specifications themselves. The curse of the industry lies in the disreputable practice of grade substituting, manipulating or juggling, wherein the existing complicated grade specifications shield or cloak misrepresentation. The consumer who buys hardwoods and is not in a position to judge the grade of a shipment is helpless. Without study and field experience, it is virtually impossible for the layman with the present grade specifications to recognize a board rapidly in terms of the grade classification.

Grading specifications on the factory-yield basis provide an opportunity for extreme simplicity, as will be apparent from the following example, in which the existing grade of No. 1 Common is given, there being printed directly underneath it a simplified grade specification on the yield basis that has been suggested as to form only. This form is even more complicated than it might be in grades where there is need of only one determining factor instead of two. Simple specifications of this character are readily understandable and would preclude disreputable practices in the substitution of hardwood grades. Both the producer and the consumer of hardwood would be provided with a simple yardstick measure of lumber values, and the easy application of such standards would do much to remove many of the difficulties that are experienced in interpreting and in the functioning of the present grades.

No. 1 Commons

(Present Grade-Basis)

Bright sap is no defect in the common grades.

Widths 3 in. and greater, not to exceed 5 per cent of 3-in. widths.

Lengths 4 ft. and greater, but not more than 10 per cent, may be 4, 5, 6 and 7-ft. lengths.

Pieces 4 and 5 ft. long, must be clear.

Pieces 3 and 4 in. wide, 6 and 7 ft. long, must be clear.

Pieces 3 in. wide, 8 to 16 ft. long, must work 66⅔ per cent clear-face in not over two cuttings; no cutting to be less than 3 ft. long by the full width of the piece.

Pieces 4 in. wide, 8 to 16 ft. long, must work 66⅔ per cent clear-face in not over two pieces in cuttings 2 ft. and over long by the full width of the piece.

Pieces 6 ft. long, 5 to 8 in. wide, may have one standard defect; pieces 6 ft. long, 9 in. and over wide, may have two standard defects.

Pieces 5 to 7 in. wide, 7 to 11 ft. long must work 66⅔ per cent clear-face in not over two cuttings; pieces 5 to 7 in. wide, 12 ft. and over long, must work 66⅔ per cent clear-face in not over three cuttings.

Pieces 8 in. and over wide, 7 to 9 ft. long, must work 66⅔ per cent clear-face in not over two cuttings; pieces 8 in. and over wide, 10 to 13 ft. long, must work 66⅔ per cent clear face in not over three cuttings; pieces 8 in. and over wide 14 ft. and over long, must work 66⅔ per cent clear-face in not over four cuttings.

No cutting to be considered which is less than 4 in. wide by 2 ft. long, or 3 in. wide by 3 ft. long.

Simplified Specifications

(Suggested as to Form Only)

Primary Determining Factor.—4 in. and over wide, 48 in. and over long, clear face.

Secondary Determining Factor.—4 in. and over wide, 24 in. and over long, clear-face. Each board must contain not less than 50 per cent primary factor and yield a total of not less than 75 per cent of primary and secondary factors combined.

Central Committee on Lumber Standards

The Hardwood Manufacturers' Institute has created an engineering department to canvass the requirements of consumers and to cooperate with all the elements properly concerned. In the automotive field, work has already been initiated with the Society of Automotive Engineers, specific contact having been made with the Passenger-Car Body Division of the Standards Committee.

Progressing from these intimate field-contacts, the entire lumber standardization program proceeds to the Central Committee on Lumber Standards that has headquarters in the City of Washington. This is an executive body that will act upon approved recommendations when all the elements are in harmony. The ultimate step in this process will be the establishing of American

lumber standards; and this comprehensive structure will include all the lumber specifications for all species, both softwood and hardwood, factory and building woods. The entire fabric will be constructed as a standardized instrument that will be worthy of the term "American Lumber Standards" and will take its place with other American standards, registered in the Bureau of Standards under the Department of Commerce. Hardwoods for factory use, in which, as has been said, the automotive industry stands second in the volume consumed, will play an important part in developing the American lumber standards and there is no question that specifications on the yield basis will rule by the general consent of all concerned.

TRAINING AUTOMOTIVE MECHANICS

AT a conference held by the Federal Board for Vocational Training, in Detroit, on Nov. 29, 1922, the trend of the discussion was influenced mainly by an outline of pertinent subject-matter that had been prepared and circulated in advance.

First consideration was accorded the questions of what type of automotive repairman is in greatest demand; whether assemblers who have learned how to install repair parts or mechanics possessing higher qualifications are the more satisfactory; why any general machine-shop experience may or may not be an asset to a prospective automotive repairman; and which of the following lines of work have value in training automotive mechanics: blacksmithing, sheet-metal work and machinist's bench-work including chipping, filing, scraping, fitting, lining-up and the like.

Two opposing opinions were expressed; one, that in addition to his ability as an assembler the prospective mechanic should have only the bench-work end of the machine-shop work included in his instruction; the other, that a good grounding in general machine-shop practice induces more workmanlike methods of repairing, is conducive to greater pride of the workman in his job and gives him a good basis for future progressive efficiency. A representative of the horological system outlined the three grades of standardized ratings for watch-repairmen as determined under the direction of the Bureau of Standards at the City of Washington. Reference was made to the fact that certification of graduate mechanics should be made as rigid as possible, the present driving licenses being quoted to show how such a system can be abused and robbed of its value. A suggestion was made that vocational schools might be graded according to their qualifications, presumably by the Federal Board, and a brief discussion centered about whether it is planned to educate men to be foremen or to be general mechanics. Further discussion related to the possibility and desirability of having the vocational schools endeavor to specialize their pupils, for part of the course, on certain vehicles to be designated by the students.

While no definite conclusion was reached regarding the subjects outlined in the foregoing paragraph, or even any preponderance of opinion expressed in regard to any one of them, the tendency seemed toward giving the pupil as much instruction and experience in the trades closely allied to the actual repairing of automobiles as might be possible; but that extremes should be avoided, such as foundry work, precision grinding and the like. It is believed that the time available, usually 12 to 18 months, is insufficient, and that the ordinary pupil would not be able to assimilate more than a limited amount of such instruction.

The general opinion appeared to be that an automotive mechanic should have some knowledge of the properties of the materials upon which he works, such as iron, steel, brass, aluminum and some other metals; also, that pupils should be given sufficient information about the heat-treating of steel to enable them to realize the danger of overheating parts when making repairs and that, possibly, in regard to minor parts, the student should be made able to approximate proper methods after he has ascertained from the manufacturer or some other source what heat-treatment, if any, should be employed for the work in hand.

With regard to whether a student should be taught any of the commercial methods of the garage business, a practically unanimous opinion was evidenced to the effect that instruction should be given in garage-business fundamentals and several opinions were given in favor of including also some instruction in salesmanship, so that the student will be assisted in selling his services to an employer and enabled to establish better contacts with customers.

Elementary instruction only was believed necessary in specialized lines such as gas-flame welding, radiator repairing, and tire and storage-battery work, the view being that actual working conditions should be the exclusive consideration in the school shop and that highly specialized tools are apparently losing ground in the larger repair-stations. However, suggestions were made as to means of obtaining shop equipment for the schools from motor-car manufacturers and sales agencies at better rates.

Concerning the extent to which technical courses in the related sciences, such as drawing and mathematics, should be considered an integral part of a course of instruction, what the subject-matter should comprise and upon what it should be based, it was thought desirable to equip a lecture-room in such a school and to have lectures delivered that would tend to tie pure science of this character to actual shop practice, but no definite opinions were expressed as to how deep into the related sciences such a course should go.

It has been stated that an important part of the training of a welder is the development in him of a "job conscience," and the questions were raised whether a similar qualification would be desirable for an automotive mechanic and, if so, how to develop it; but the only suggestion made was that machine-shop training would aid materially in such an accomplishment.

In view of the short time available each evening, it was brought out that any comprehensive course, such as giving shop training on repair work to beginners or making the evening courses available to those who can secure shop experience on the job as a part of their regular work, would extend over too long a period; but, starting with men, who have had little or no mechanical training, 6 weeks was considered entirely too short a period for the adequate training of an automotive mechanic.

Regarding certain phases of training and whether they can be given better in a school or in an outside garage or service-station, it was explained that a majority of the schools bring in outside work in an endeavor to simulate garage operating conditions and that some schools maintain separate garages for this purpose.

It remained an open question as to what agency could best assume the responsibility for setting up training standards and job specifications, if these were deemed advisable for application to automotive repairmen.

A Double-Reflector Type of Head-Lamp

By Bruno Heymann[1] *Illustrated with* Photographs and Diagrams

THE Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society conducted a number of road tests with head-lamps in 1918 for the purpose of establishing a set of rules as a basis for the approval of road-lighting devices. As a result of the experiences gained, these rules were revised Feb. 9, 1922, and were published.[2] These rules were approved at a recent meeting of the motor-vehicle administrators of 10 States. This action undoubtedly will pave the way for their establishment as the recognized standard in this Country by the American Engineering Standards Committee.

It seems that the efforts of the American designers have been directed mainly to the production of new lenses, tilting mechanisms and other devices applicable to existing ordinary head-lamps representing on the whole makeshifts. Very little attempt has been made to approach the problem from an entirely new angle. It has also been advocated recently that the highways of the Country be illuminated as a solution of the lighting problem. Such an installation would be not only very wasteful, as at least some of the lamps would have to burn all night, traffic or no traffic, but also very undesirable from the standpoint of the driver, since lack of contrast on the road would prevent the quick vision of obstacles. Furthermore, the passing at regular intervals of light-sources of high intensity would produce periodic contraction and dilation of the iris and finally eye-strain. These objections are patent, not to mention the most formidable argument against it, which is the high cost of installation and maintenance that the taxpayer would oppose most strenuously. The only alternative to this proposal is to have each vehicle its own light-source for the illumination of the road.

Glare Problem in Europe

A brief resume of the glare problem in Europe shows that the authorities abroad are struggling with the same difficulties, striving to find a basis for a satisfactory head-lamp specification. Since the end of May, 1922, a new law has been in operation throughout France, limiting the vertical spread of the beam projected by vehicle head-lamps to 1 m. (39⅜ in.) from the level ground. Head-lamps that do not comply with this requirement are prohibited. The operation of powerful automobile head-lamps, undimmed, within the city limits, is also prohibited. For this reason many automobiles, particularly taxis, can be observed driving through the streets of Paris equipped only with old-fashioned oil-lamps. The situation in London is similar. After all, no satisfactory head-lamp has been developed in France to date.

No uniform law with respect to lighting vehicles is in existence in Germany at present. In a general way local ordinances have one provision in common, namely, that in driving through city streets the head-lamps must be switched off entirely or must be dimmed. The head-lamps must also be dimmed on the country highways in meeting other vehicles. This is rarely done, however. Very elaborate constructions for tilting and sliding spherical mirrors and cups around and over the lamp-bulbs are being marketed in an attempt to solve the glare problem. It is safe to say that these mechanisms are rarely operated, as their manipulation is left to the discretion of the driver.

The Departmental Committee on Lights on Vehicles of the Ministry of Transport of Great Britain[3] states that it has conducted very extensive experiments on the best standard electric head-lamps and devices put forward today as a solution of the dazzle problem. The Committee defines glare or dazzle as "such an intensity of light reaching the eye of an observer as to cause material interference with his normal vision, under the conditions existing at the time of observation." Correct as this definition is, it appears to me that it should be somewhat extended, since the degree of dazzle in addition is a function of the total flux of light reaching the eye of an observer as well as a function of the contrast in intensity between the light-source and its background.

These well-known facts have been confirmed again in a series of head-lamp experiments carried out recently by Dr. G. Gehlhoff and Dr. H. Schering at the Goerz plant in Germany. In their report,[4] the authors state that the permissible intensity of a 9-in. head-lamp on a well-lighted street is 27,000 apparent cp.; while, on a dark country highway, an intensity of only 900 apparent cp. constitutes the extreme allowable upper limit.

In the British tests,[5] more than 100 lamps and devices were thoroughly tested in the laboratory, some of them being also subjected to the road test. This test, originated by the Royal Automobile Club and standardized by the British Engineering Standards Association, was approved and adopted by the Ministry of Transport. The result of these tests revealed the fact that not one wholly satisfactory and practicable lamp or dimming device to avoid glare has been discovered. The Committee reaches the conclusion that "prevention of dazzle under every condition and circumstance is at present unattainable with a safe driving-light."

The report furthermore points out that dimming devices cause such a reduction of intensity in the driving light as to render them unsuitable for the faster moving vehicles, and that a much more promising solution of the problem lies in modifications of the design of the head-lamp by which improved control over the beam of light will be attained.

In Appendix 1 of the report, the Committee finally records a detailed specification of head-lamps for the information and guidance of designers and manufacturers, in which the two essential characteristics of head-lamps are

(1) A penetrating beam for distant illumination
(2) A beam of diffused light to illuminate the fore-field

Major A. Garrard, who has been associated with the tests made for the Ministry of Transport Committee[5] in

[1] M.S.A.E.—Mechanical engineer, dean of the California School of Mechanical Arts, San Francisco.

[2] See *Transactions of the Illuminating Engineering Society*, vol. 14, p. 64; see also S.A.E. Handbook, vol. 1, p. B7.

[3] See Third Interim Report, Sept. 30, 1921; see also *Transactions of the Optical Society* (London), vol. 23.

[4] See *Transactions of the Optical Society* (London), vol. 23.

[5] See *Transactions of the Optical Society* (London), vol. 23.

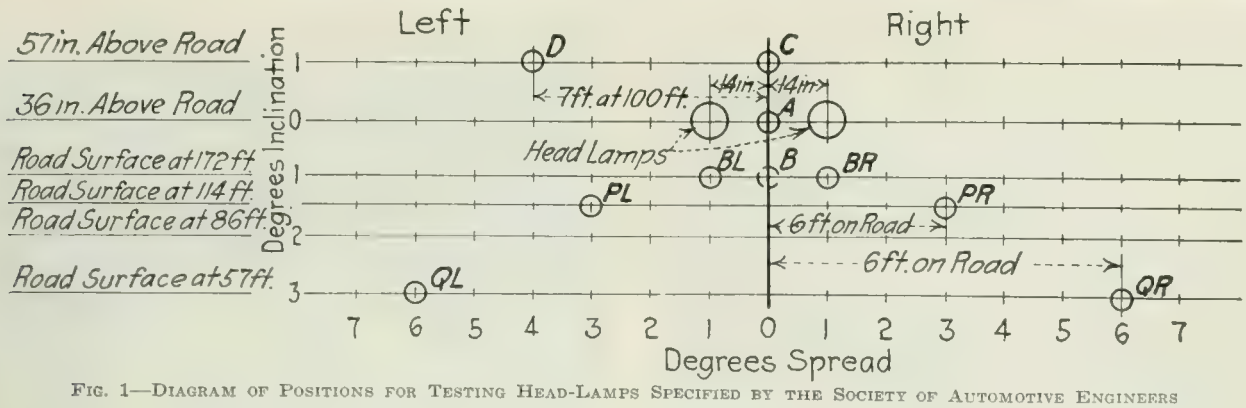

FIG. 1—DIAGRAM OF POSITIONS FOR TESTING HEAD-LAMPS SPECIFIED BY THE SOCIETY OF AUTOMOTIVE ENGINEERS

an excellent paper on Motor-Car Headlights presented to the Illuminating Engineering Society in London,[6] March 17, 1921, discusses the rules formulated by the American Illuminating Engineering Society, analyses the glare problem and finally states that the essentials of a head-lamp that will keep the light below the eyes and will at the same time give sufficient illumination for safety both of the vehicle and of others on the road are

(1) A fairly wide but relatively dim beam, with a well defined upper limit, 3 or 4 ft., from the ground so as to illuminate hedges, ditches and the road in front of the car

(2) A central broad but shallow penetrating beam of much greater intensity with a well defined upper limit of 3 or 4 ft. from the ground for distance observation

(3) A diffused or subdued beam having a very wide angle, and corresponding to the light obtained directly from the filament

In conclusion, therefore, the question of a satisfactory driving light is not one merely of intensity but also one of distribution.

[6] See *The Illuminating Engineer* (London), vol. 14, p. 920.

Lenses or systems of lenses, owing to their optical characteristics, cannot efficiently produce the results demanded by Major Garrard, and it seems that head-lamps constructed of mirrors and combinations of mirrors give more promise of success. It is evident that, to attain high efficiency, the total flux from the light-source must be collected and controlled so that a large part, the primary rays, will be projected in a brilliant, shallow beam into the distance, and the remainder, the secondary rays, utilized for fore-field and side-field illumination.

ANTI-GLARE HEAD-LAMP

In thus reviewing the situation, here and abroad, the outstanding fact is revealed that no practical solution of an all-round satisfactory, anti-glare head-lamp has yet been discovered. It is the purpose of this paper to describe a new and most promising device invented and developed by an engineer in San Francisco. This new design represents a radical departure from the beaten path of head-lamp construction and approaches in a marked degree the ideal driving-light outlined in Major Garrard's paper.

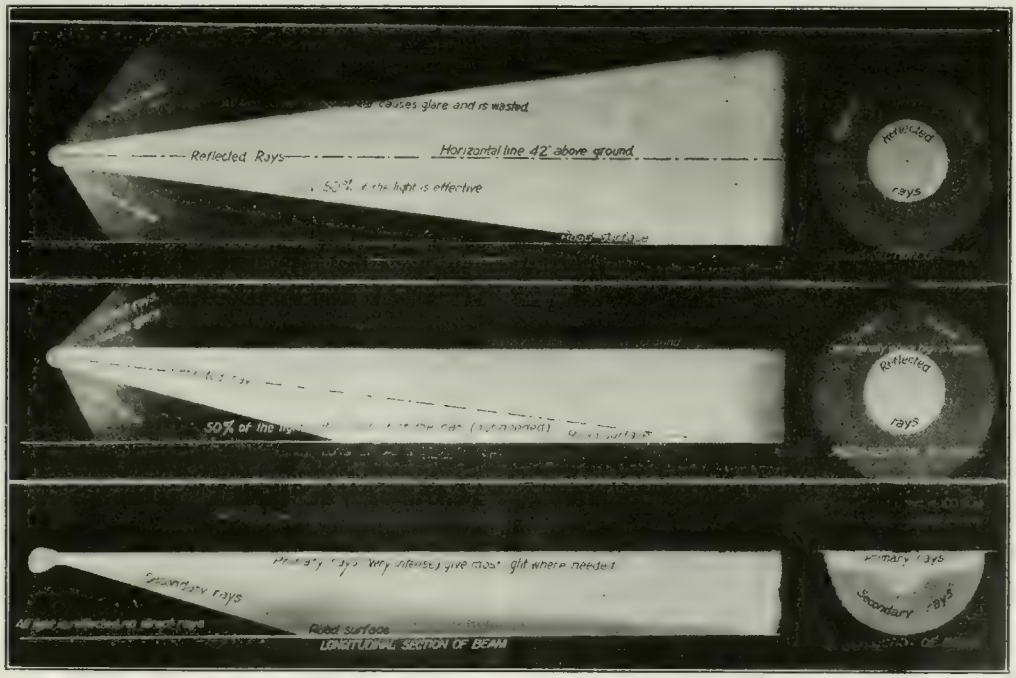

FIG. 2—COMPARISON OF THE CHARACTERISTICS OF A BEAM ISSUING FROM AN ORDINARY FIXED PARABOLOID REFLECTOR UNDER NORMAL CONDITIONS AND WHEN DEFLECTED EITHER MECHANICALLY OR OPTICALLY AND THAT ISSUING FROM A DOUBLE-REFLECTOR HEAD-LAMP

The anti-glare head-lamp in its present form is the outcome of painstaking study and research work on the part of the designer during the past 6 years, involving an entirely new principle in light projection using two reflectors. Its unusual performance is accomplished by a combination of a 6-in. paraboloid reflector with an oblique projecting reflector. Through an extraordinary control of the beam, a light distribution is accomplished that has never been attained before in a practical head-lamp. It produces two distinct fields of illumination, one of high intensity for distance observation and another of moderate intensity for side and fore-field illumination.

The beam is projected through a vertical slit ½ in. wide and 4 in. long. All the rays from the light-source pass through this opening. None is intercepted. They are projected almost entirely below a horizontal plane, 42-in. above the ground.

Fig. 1 is a diagram of specified test positions for testing head-lamps recommended by the Society.[1]

Fig. 2 gives the characteristics of the beam issuing from an ordinary fixed paraboloid reflector at the top of the illustration, the same beam deflected either optically or mechanically in the central portion and that of the double-reflector lamp at the bottom. We are familiar with the objectionable features of the beam coming from the ordinary head-lamp, with its maximum intensity in the axis of the beam, with its glare and its waste of the upper half of the light flux. The tilted reflector, in an attempt to reduce glare, illuminates the roadway with a maximum intensity too close to the car, where it is not needed, and where it is very harmful to the vision of the driver in his endeavor to observe distant objects. The tilted beam illuminates these remote objects only with a reduced intensity where high intensity is paramount.

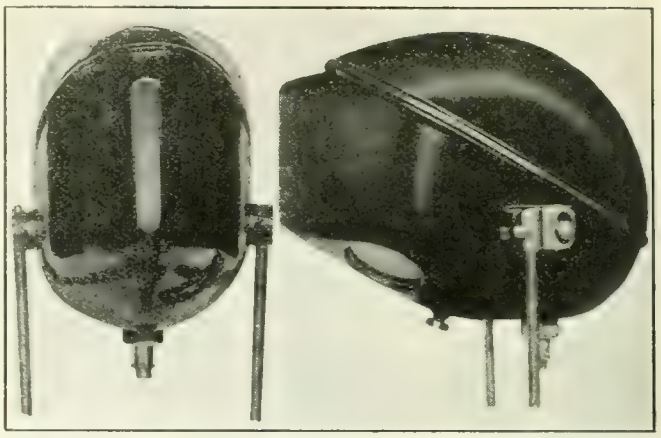

Fig. 5—Front and Side Views of the Double-Reflector Lamp

Fig. 3—Illumination of the Road with a Double-Reflector Head-Lamp

[1] See S A E Handbook, vol. 1, p. B8.

Fig. 4—Interior of a Theater Illuminated with a Double-Reflector Lamp

In the beam projected by the double-reflector lamp the maximum intensity is distributed uniformly across the top of a broad field of illumination, as if the wasted upper half of the ordinary beam had been folded back over the lower half, doubling its intensity. The primary rays of high intensity run parallel to the roadway, spreading approximately 50 ft. in a distance of 100 ft. The secondary rays of lower intensity illuminate the regions directly in front and to the side of the car. Additional side and fore-field illumination is obtained by an independent, small side-lamp integral with the housing. This side-lamp can be used also as a parking light.

Fig. 3 shows the illumination of the road. The ob-

server stands directly in front of the head-lamp, looking toward it. The small vertical white speck in the distance indicates the aperture of the lamp. The distance is approximately 100 ft. Note the absence of glare and the distribution of the light on the roadway by a single lamp.

Fig. 4 shows the interior of a theater, looking toward the stage. The position of the observer is directly behind the lamp. Note the 50-ft. spread of the beam on the wall 100 ft. distant, the moderate fore-field illumination and the high intensity of the beam across the horizontal top line, 42 in. above the ground. Note also the uniform height and the sharp definition of beam.

TABLE 1—HEAD-LAMP TEST DATA

		Apparent Candlepower at Test Positions							
		A	*B*	*C*	*D*	*E*[8]	*F*[8]	*P*	*Q*
1922 Limits of the Illuminating Engineering Society and the Society of Automotive Engineers	Max	1,800	7,200	800	. . .	1,200	1,200	5,000	2,000
	Min	6,000	....	2,400	800	....	.....	.....	.....
Head-Lamps and Lenses Tested		Results of Tests							
Double-Reflector Head-Lamp[9]		9,000	13,000	800	700	12,500	16,500	19,000	4,000
Lens T[10]		4,200	10,750	2,150	790	1,390	6,750	.....	.
Lens U[10]		2,050	7,550	910	540	1,525	14,000	. ....	
Lens V[10]		3,900	11,000	1,900	535	1,015	5,400	. .	
Lens W[10]		2,000	6,100	970	510	815	9,750	..	.
Lens X[10]		3,350	6,700	1,900	640	1,010	5,750	.	.....
Tilting Reflector Y[11]		1,165	1,640	990	495	1,120	8,230	.	.
Tilting Reflector Z[12]		3,710	4,930	2,110	915	...	...	.	. .

Note:—Many states limit bulb-candlepower for head-lamp lenses in addition to limiting the tests, but such limitations do not apply to the double-reflector head-lamp; any size of bulb can be used, because glare is eliminated.

[8] Test positions *E* and *F* were omitted in the 1922 Revised Rules.

[9] Tests were conducted by the engineering department of the National Lamp Works of the General Electric Co., in the fall of 1920. Each head-lamp was equipped with a 6-in. paraboloid reflector and a 36-cp. bulb. The lamps were 42 in. apart, and readings were taken at a distance of 45 ft.

[10] Data supplied by the division of motor vehicles of one of the states that has adopted the rules of the Illuminating Engineering Society. The lenses are of leading American makes.

[11] Each lamp was equipped with a 9-in. paraboloid reflector and a 14.5-cp. bulb. The lamps were 26 in. apart.

[12] Each lamp was equipped with an 8⅝-in. paraboloid reflector and a 16.4-cp. bulb. The lamps were 25¼ in. apart.

In Table 1, test data are given comparing the lamp with double reflectors and a few of the best known approved lenses and devices with the requirements formulated by the Illuminating Engineering Society and the Society of Automotive Engineers. These rules specify the use of 21-cp. bulbs in making head-lamp tests. All State traffic-laws in approving lenses and other devices also impose limitations upon the candlepower of bulbs to be used. These provisions are made with a view to limiting glare. The double-reflector lamp practically eliminates glare, such limitations become obsolete and bulbs of any candlepower can be used.

The peculiar body shape of the double-reflector lamp is revealed by a study of Fig. 5, which gives front and side views of the newest design. The interior is readily accessible by a removal of the air-tight cap, held in position by one clamp. The front slit, as well as the side opening for the parking light, is plainly visible.

Fig. 6 gives a vertical section through the lamp in which *a* is a 6-in. paraboloid reflector, and *b-c* an in-

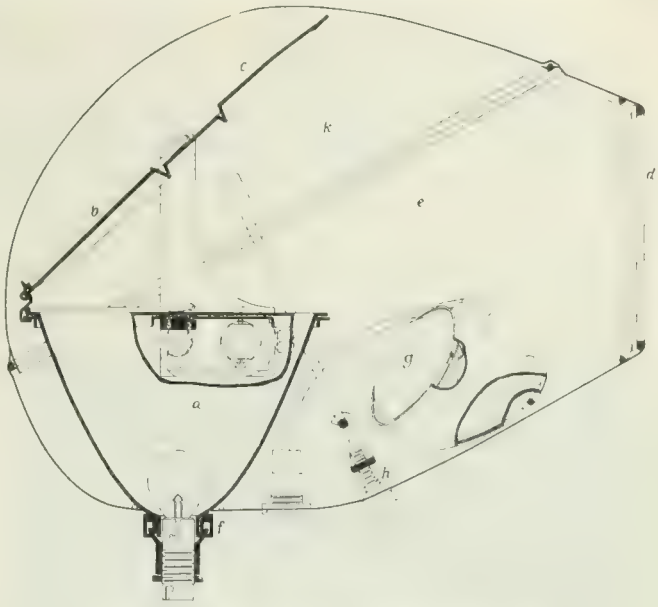

FIG. 6—VERTICAL SECTION THROUGH THE LAMP

clined reflector, redirecting and reshaping the light beam as it is received from *a*. Both reflectors are manufactured from sheet brass, highly polished and silvered; they are mounted so that they constitute a rigid, complete unit. All light rays meet in a vertical line at the aperture *d* before leaving the housing *e*. The housing is pressed from light-gage sheet-steel stock and black enameled. The focusing adapter *f* permits a minute adjustment of the position of the filament in all directions. A small

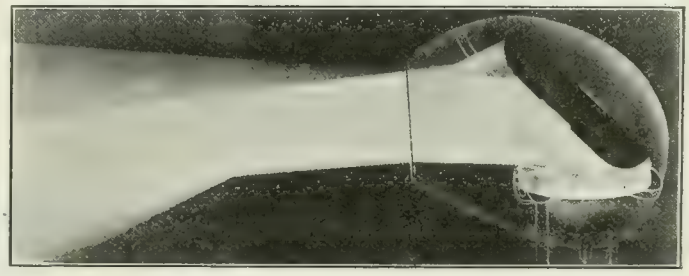

FIG. 7 PHANTOM VIEW OF THE LAMP

spherical reflector used for side lighting is indicated at *g*. The cover *k* is held securely in position by the clamp *h*. The weight of one lamp complete is approximately 7 lb.

For the purpose of illustrating the operation of the lamp and its light control, a phantom view is shown in

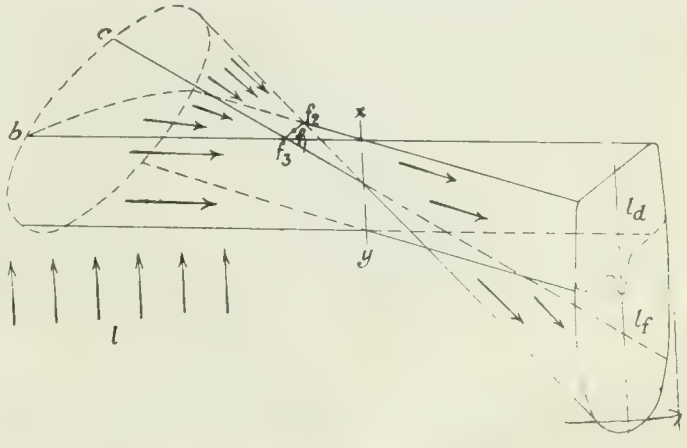

FIG. 8—DIAGRAM OF LIGHT DISTRIBUTION

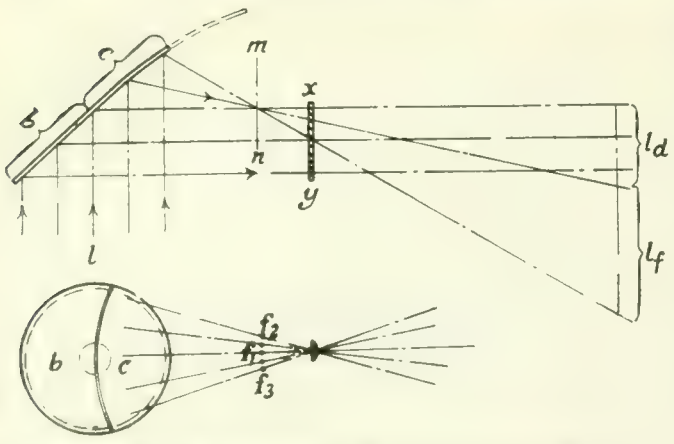

FIG. 9—MERIDIAN SECTION AND PLAN VIEW OF THE HEAD-LAMP

Fig. 7, a pictorial representation in Fig. 8 and a meridian section with a plan view in Fig. 9. Here l represents the flux of light as it is leaving the lower vertical reflector. In their upward path the rays are intercepted by the inclined reflector b-c, redirected and reshaped into two distinct fields of intensity l_d and l_f. This latter reflector is a surface of rotation, whose generatrix consists of two distinct branches and whose axis is x-y. The lower branch b is an oblique straight line forming an angle of approximately 45 deg. with the vertical axis x-y and generating the surface of the frustum of a cone. This reflecting surface collects the bulk of the light rays and, in projecting them, furnishes the powerful, penetrating beam l_d for distance observation as it would appear on a vertical screen placed in front of the lamp. The upper branch c is an arc of a parabola, having its axis at m-n and its focus at f_1. The reflecting surface generated by rotating this parabolic arc about the axis x-y produces the field l_f of moderate intensity for the region directly in front and to the side of the car in addition to strengthening the field l_d. It will be observed that the light rays from c cross first on a horizontal circular arc f_2-f_3 and then again on the vertical line x-y.

The mirror, as manufactured, differs slightly from this theoretically correct surface to compensate for the absence of reflected light from the base of the bulb and for the purpose of radiating direct rays from the source.

The lower portion of the surface b is actually generated, not by a straight line but by an arc of a parabola of a large parameter, whose vertical axis and focus are to be found to the left of the mirror. This modification has not been shown in the illustration for fear of obscuring a perfect understanding of this description.

The Pressure-Volume-Quantity Indicator-Card

By Thomas Midgley, Jr.[1] and Robert Janeway[2]

Indiana Section Paper *Illustrated with* Photographs and Charts

IN the case of the internal-combustion engine, where virtually every separate portion of explosive mixture behaves differently, the usual thermodynamic interpretations of the pressure-volume indicator-card, as applied to steam engineering, have little value. In internal combustion, the pressure-volume diagram is of value only as an expression for the product of the force exerted upon the piston-top times the distance through which the piston moves.

The paper begins with the fundamental phenomena and develops therefrom a diagram such that each fuel-mixture particle can be properly exposed for analysis during the process of combustion. This is termed the pressure-volume-quantity card, and it is described in detail and illustrated. An extended consideration of its surfaces follows, inclusive of mathematical analysis. Work and losses are discussed, including the mathematical derivation of the so-called pseudo-hysteresis loss, the gross and the net work done; a comparison is made with the pressure-volume card; the indicated thermal efficiency relation is treated; a representation of detonation is presented; and the important points of the paper are summarized.

THE application of thermodynamics to the internal-combustion engine has been notably lacking in beneficial results. This is primarily because of the fact that the so-called thermodynamics of internal combustion has been an extension of the science as it is applied to steam engineering, rather than a development strictly applicable to internal combustion and based upon its fundamental phenomena.

To be more specific, the pressure-volume indicator-card, which is ordinarily considered as a part of thermodynamics, is essentially nothing more than elemental energetics representing in a graphical manner the product of force times distance. In steam engineering, certain curves of this diagram have been found to have thermodynamic interpretations. These interpretations have been sufficiently reliable to yield the necessary information as to the heat interchanges occurring during the process of converting heat energy into mechanical energy. This is due to the fact that any one portion of steam within the steam-engine cylinder can rightfully be considered as behaving in identically the same manner as any other portion. But, in the case of the internal-combustion engine, where virtually every separate portion of explosive mixture behaves differently, such interpretations have no value. Consequently, in internal combustion, the pressure-volume diagram is of value only in its fundamental application; that is, as an expression for the product of the force exerted upon the piston-top times the distance through which the piston moves. So far as internal combustion is concerned, all attempts to convert this card into useful thermodynamics have been unsuccessful.

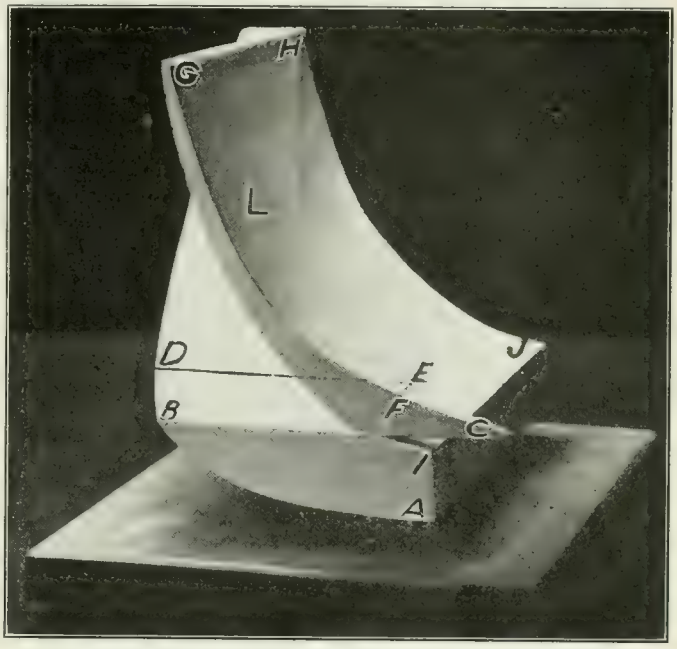

Fig. 1—Pressure-Volume-Quantity Card for Normal Combustion

The purpose of this paper is to begin with the fundamental phenomena and develop therefrom such a diagram that the behavior of each particle during the process of combustion can be exposed for analysis properly. Unfortunately, there is at present a lack of quantitative fundamental data to draw from, and this very lack of data can be attributed to the fact that heretofore such a system as we present in this paper has not been available. Therefore, to develop the theoretical hypotheses, it has been found necessary to make many quantitative assumptions. It has been found expedient also to use some approximate mathematical expressions where the true expressions are extremely difficult, if not impossible, to integrate. This development is presented therefore, not in the belief that it is a finished product, but rather that it presents for the first time a method of truly representing the thermal relationships existing in internal combustion. It gives at once a better understanding of the thermodynamics involved in internal combustion in a qualitative way and, with these qualitative conceptions before the engineer, quantitative data will follow in due course of time; so, the thermodynamics of internal combustion may eventually be placed upon as sound and profitable a basis as the thermodynamics of steam engineering has proved to be.

The Pressure-Volume-Quantity Card

Fig. 1 is a photograph of the theoretical card development that constitutes the major portion of this paper. This card is a solid figure plotted so that the vertical

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axis represents pressure, P; the left-to-right axis, volume, V; and the front-to-rear axis, progressive portions of the charge, Q.

On such a diagram the work done by an individual particle is represented by the cross-section of the figure as cut by a plane of Q = a constant. The work done by or upon the entire charge is represented by total volumes. This particular diagram is a theoretical card of 100-per cent volumetric efficiency with perfect scavenging. It makes no allowance for the mechanical shortcomings of the engine, valve mechanism and ignition. However, an effort has been made to make due allowance for the heat losses to the jacket occurring in an engine.

At point A of the card in Fig. 1, the piston is at bottom dead-center. It is assumed that the cylinder contains a charge of theoretical mixture proportions at atmospheric pressure and temperature plus a quantity of exhaust gas equal to the clearance volume. Compression takes place along the compression line $A - B$, the piston arriving at top-center B where ignition takes place. The piston is assumed to halt at top-center during the process of combustion. The first particle of gas that burns expands from B to C, this expansion being caused by three-quarters of its heat of combustion. The remaining one-quarter of the heat of combustion of the particle is assumed to be unavailable on account of equilibrium conditions between the uncombined atoms from the fuel and the products formed by the partial combustion of the particle under consideration. The foregoing discussion considers simply the first particle of mixture that has entered combustion. As an aggregate of fuel particles undergo combustion, it is evident that the pressure will be raised; so, by the time one-tenth of the total mixture has been burned, the unburned portion of the mixture will have been compressed adiabatically until its pressure has been raised to the point D. When the next particle of the gas undergoes combustion, it burns along the line $D - E$. This process is continued until combustion of the charge is complete.

While the gas ahead of the flame-front is being compressed adiabatically, the portion of the charge that has been burned is also being raised to the same pressure; but, in the latter case, the character of the compression is not adiabatic, because the gas is losing heat to the cylinder-walls by radiation and conduction. The information on this compression is meager and far from complete. However, the information that is available indicates that the nature of this compression approaches isothermal conditions more nearly than adiabatic. No material departure from these conditions is made if, in the absence of accurate data, it is assumed that this compression is of such a nature that during its compression the burned gas comes to precisely the same conditions of temperature and pressure as that portion of the gas which has just completed combustion. Thus, the burned gas which has been compressed to F is assumed to be at the same temperature and pressure and to have the same specific volume as the gas at E. This process of compression to the rear of the flame-front continues until all the gas has been burned, when its condition is represented by the line G-H.

Expansion now takes place along a surface, which can be determined by actual indicator-cards, to the end of the stroke, I-J, at which point the exhaust-valve opens and conditions return to atmospheric, thus completing the card.

It may be observed that the burned gas which has been compressed along a near isothermal and expanded along a near adiabatic has thereby caused work to be done upon it. This work is represented by the volume L. Applying an electrical term, this volume, which represents a loss of work, can be called the pseudo-hysteresis loss. The positive volume of the card represents the gross work that has been done by the gas. The difference between the gross work and the pseudo-hysteresis loss is then the net work. This difference should equal the work delivered to the piston and equal the area of the conventional pressure-volume card.

Detailed Consideration of Surfaces

By the very nature of the construction of the diagram, the front and rear surfaces are simple flat planes of equations $Q = 0$ and $Q = 1$, respectively. Assumptions, research and approximations are unnecessary in these cases.

Up to the point at which ignition occurs, the equation governing the compression surface can be determined from an actual indicator-card, and the surface can be extrapolated from this point to the completion of combustion. The general equation for this surface should be $PV^y = K$. No assumptions or approximations are necessary here; but, to justify the extrapolation thoroughly, further research work should be carried on to determine definitely that the unburned gas ahead of the flame-front does compress adiabatically.

The combustion surface is one of the most interesting developments of this theoretical work. It has been shown, in a paper[3] entitled Molecular Movements during Combustion in Closed Systems, presented at a meeting of the Pennsylvania Section in 1921, that the general equation for an intercept of this surface by any vertical plane, Q = a constant, should be

$$P_1 - P = W^2 \, g \, (V - V_1) \qquad (1)$$

where

$g = 32.2$
P = the pressure
P_1 = a constant
V = the specific volume
V_1 = a constant
W = the quantity of gas entering the flame-front per unit time

This intercept is a straight line of slope proportional to the square of the reaction velocity. In normal combustion, the departure of this line from the horizontal is so slight that it need not be taken into consideration. It is only when detonation occurs that the slope of this line plays an important part in the diagram. The projection of the combustion surface upon a vertical plane, V = a constant, is determined in the following manner:

Since at any point during combustion the sum of the volumes of the burned and the unburned portions of the mixture must equal the clearance volume, an expression can be derived on this basis relating the pressure to the quantity of fuel burned. The specific volume of the unburned portion of the gas at any pressure is defined by the point on the compression line corresponding to that pressure; likewise, the specific volume of the burned portion of the gas at the same pressure is defined by the corresponding point on the line $G - C$. Then, if Q represents the portion of fuel burned at any point, the clearance volume, C_1, is

$$(Q \times V_1) + (1 - Q) \, V_1$$

where

$V_1 = (K/P)^{\frac{1}{y}}$, the specific volume of the unburnt gas (adiabatic compression)

[3] See The Journal, May, 1922, p. 361.

$V_2 = (K/P)^{\frac{1}{y}} + \Delta V$, the specific volume of the burnt gas

$y = C_p/C_v$, the ratio of the specific-heats of the gas

$\Delta V = C'/P$, as derived in equation (3) for constant-pressure burning

Substituting,

$$V_2 = (K/P)^{\frac{1}{y}} + C/P$$

Then,

$$Q\ [(K/P)^{\frac{1}{y}} + C'/P] + (1 - Q)\ (K/P)^{\frac{1}{y}} = C_1$$

$$Q\ (C'/P) + (K/P)^{\frac{1}{y}} = C_1$$

$$Q = P/C[C_1 - (K/P)^{\frac{1}{y}}] \qquad (2)$$

The actual variation of P with Q, as determined by equation (2), departs so little from a straight-line law that such a relation can be assumed with inconsiderable error. The equation resulting from this assumption is

$$P = mQ + b$$

Where

b = the compression pressure
m = the total pressure-rise during combustion
P = the pressure in pounds per square inch
Q = the fraction of mixture burned

The situation with respect to the combustion surface can be summarized by saying that very little more research work need be done to make a proper determination of this surface. However, the true equation of this surface is a very complex function, because it is a combination of equations (1) and (2); but, during normal combustion and within the limits of reasonable compression-ratios, the equation of this surface departs so little from the simple expression $P = mQ + b$ that the variations can be considered negligible, and the mathematics can be simplified greatly by adopting this expression as the equation of the combustion surface. While only an approximation, its deviation from the true value is less than 0.5 per cent.

Burned-Gas Compression-Surface

In deriving the expression for the burned-gas compression-surface, the first essential is the determination of the percentage of the heating value of the fuel that is available before equilibrium conditions are set up between the uncombined atoms and molecules of the fuel and the products of combustion. This equilibrium condition has commonly been referred to by engineers as dissociation, and a considerable amount of experimentation and numerous calculations have been made by a number of investigators in attempting to settle this much disputed point. There is as yet no agreement of opinion on this subject, and further experimental work is necessary before it can be established definitely. The net result of the theoretical investigation reported in this paper indicates that the mean average of available heat is about 75 per cent of the total heating value of the mixture. The use of this value will yield net results that agree with practice. In constructing this theoretical diagram, therefore, we have assumed that each particle of fuel, upon combustion, liberates 75 per cent of its total heating value.

The next point to determine is the nature of the compression of the burned gases. Careful analysis of the work of Woodbury, Lewis and Canby[4] yields the suggestion that gases to the rear of the flame-front are compressed approximately in accordance with isothermal conditions, giving up heat by conduction to the walls as well as by radiation. This point deserves further investigation. It is important to establish the magnitude of the pseudo-hysteresis loss, because it can be reduced materially by proper engine design and operation. Inasmuch as there are no exact data covering the nature of this compression, we have felt at liberty to select a type of compression that approximates an isothermal and lends itself to simple mathematical analysis. This assumption is simply that, when each particle of fuel has reached the end of its combustion, all the gas previously burned has been so compressed that it has assumed the same conditions of pressure, temperature and specific volume as that of the particle under consideration. In other words, the assumption is that the burned gas is compressed along the same curve as that which limits the expansion of the burning particles, and which can be seen from its equation, $V = C/P + (K/P)^{\frac{1}{y}}$, to be nearly an isothermal.

The derivation of the equation based upon these assumptions is as follows: If H equals the heat added during constant-pressure burning,

$$H = WC_p\Delta T$$

where

C_p = the constant-pressure specific-heat
ΔT = the temperature rise
W = the weight of the gas burned

Then, for any particle, ΔW, and where h equals the available heat per unit weight of the gas,

$$\Delta W \times h = \Delta W C_p \Delta T$$
$$\Delta T = [(V_2/V_1) - 1]\ T_1$$
$$T_1 = (PV_1 \times 144)/R$$

where

P = the pressure in pounds per square inch
$R = 778\ (C_p - C_v)$, the quantity within the parenthesis being the difference between the constant-pressure and constant-volume specific-heats
T_1 = the initial absolute temperature
V_1 = the initial specific volume
V_2 = the final specific volume

then

$$h = C_p(V_2 - V_1)[P(144/R)] - w \times H\ [C_c - (C_1[p_a/p_s])]$$

where

C_c = the volume of the cylinder
C_1 = the clearance volume
H = the heat value per pound of fuel
h = the available heat per pound of mixture
p_a = atmospheric pressure
p_s = the suction pressure

$$P\ (V_2 - V_1) = hR/C_p \times 144 = C \qquad (3)$$

But $V_1 = (K/P)^{\frac{1}{y}}$, from the adiabatic compression of the unburnt gas. Therefore, equation (2) for the curve limiting the expansion, and for the compression of the burned gas becomes

$$V_2 = C/P + (K/P)^{\frac{1}{y}} \qquad (4)$$

The expansion surface can be determined from an actual indicator-card, since its intercept with a plane, Q = a constant, corresponds to the expansion line of the indicator-card. In the theoretical card under discussion, the equation of the expansion surface has been assumed to be $PV^y = A$. No further assumptions are necessary and no approximations are used; so, no research work is necessary on this surface.

Work and Losses

The pressure-volume-quantity card will be observed to consist of two separate volumes; the smaller is called the

[4] See The Journal, March, 1921, p. 209.

pseudo-hysteresis loss, the larger being termed the gross work. The difference between these two volumes represents net work, and it should correspond to the area for work on the conventional pressure-volume card. To determine these volumes it is simply necessary to integrate between the bounding surfaces. The pseudo-hysteresis loss will be considered first.

DERIVATION OF PSEUDO-HYSTERESIS LOSS

Basic Equations

$V = C/P + (K/P)^{\frac{1}{y}}$ (Compression of the burnt gas. $C = P\Delta V$) (5)

$V = (A/P)^{\frac{1}{y}}$ (Adiabatic expansion) (6)

$Q\,(C/P) + (K/P)^{\frac{1}{y}} + (1 - Q)\,(K/P)^{\frac{1}{y}} = C_1$ (Clearance volume) (7)

For all practical purposes, the pressure varies with the amount of fuel burnt, Q, according to a straight-line law.

$P = mQ + b$ (approximately) (8)

where

b = the compression pressure
m = the total pressure-rise during combustion
Q = the fraction of the charge burnt

$PV^y = K$ (Compression of the unburnt gas) (9)

The loss is determined by the integration of the expression

$$\int_{Q_1}^{Q_2}\int_{P_1}^{P_2}\int_{V_1}^{V_2} dQ\,dP\,dV$$

The limits of the integration are

P = Final pressure
$P_1 = mQ + b$
$Q_1 = 0$
$Q_2 = 1$
$V_1 = (A/P)^{\frac{1}{y}}$
$V_2 = C/P + (K/P)^{\frac{1}{y}}$

Substituting the limits given, we obtain

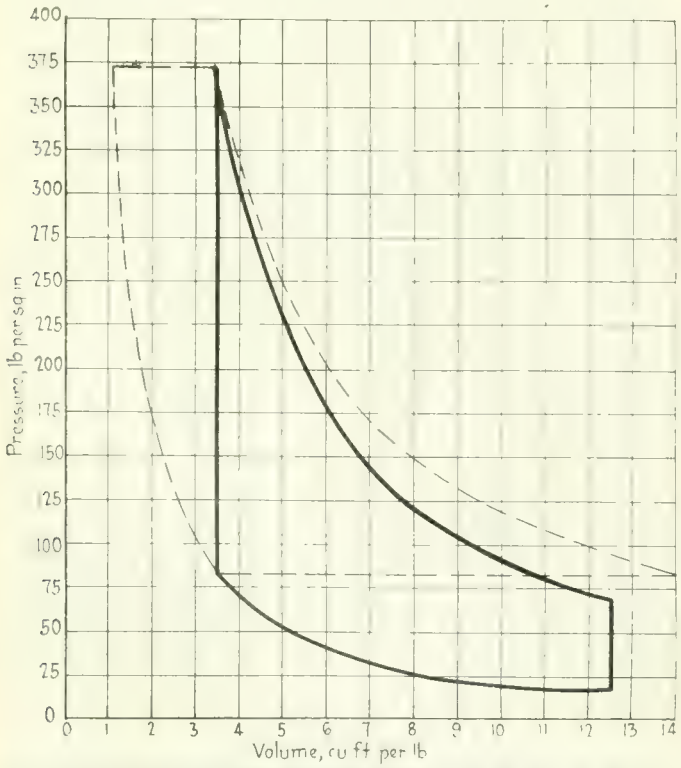

FIG. 2—DIAGRAM SHOWING THE NET WORK DONE BY THE GASES AND THE WORK DELIVERED TO THE PISTON IN A SPECIFIC CASE

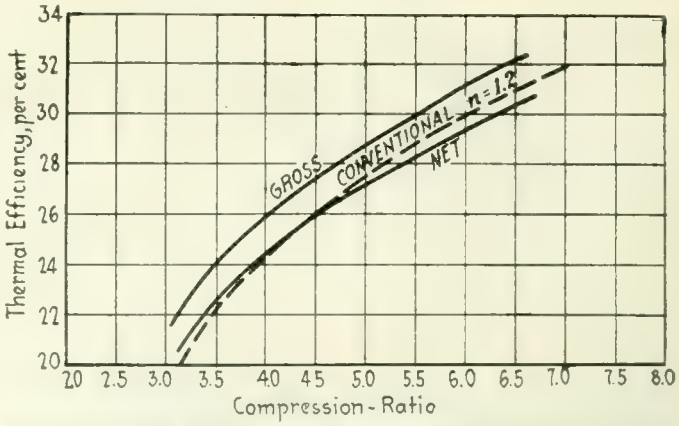

FIG. 3 THERMAL EFFICIENCIES FOR DIFFERENT COMPRESSION-RATIOS AS CALCULATED BY THE EQUATIONS BASED ON THE PRESSURE-VOLUME-QUANTITY CARD

$$\text{Loss} = \int_0^1 \int_{mQ+b}^{P_2} \int_{(A/P)^{\frac{1}{y}}}^{C/P + (K/P)^{\frac{1}{y}}} dQ\,dP\,dV$$

Integrating gives

$$\text{Loss} = (K^{\frac{1}{y}} - A^{\frac{1}{y}})/(-1/y+1)\,[P_2^{-\frac{1}{y}+1} - (P_2^{-\frac{1}{y}+2} - P_c^{-\frac{1}{y}+2})/(P_2 - P_c)\,(-1/y+2)] + C - [(CP_c/[P_2 - P_c])\,(\log P_2/P_c)]$$

GROSS WORK DONE

Basic Equations

$PV^y = K$ (Compression of unburnt gas) (10)
$PV^y = A$ (Expansion line) (11)
$P = mQ - b$ (Combustion surface) (12)

The card can be divided into two parts at the plane P equals compression pressure, and the two volumes thus obtained can be integrated separately. Then,

$$\text{Gross Work} = \int_{Q_1}^{Q_2}\int_{P_1}^{P_2}\int_{V_1}^{V_2} dQ\,dP\,dV + \left[\int_{V_c}^{V_d} (P_c - P)\,dV\right]$$

where

$P = K/V^y$
P_c = compression pressure $= b$
V_c = clearance volume
V_d = cylinder volume

The limits used in the integration are

$P_1 = b$
$P_2 = mQ + b$
$Q_1 = 0$
$Q_2 = 1$
$V_1 = (K/P)^{\frac{1}{y}}$
$V_2 = (A/P)^{\frac{1}{y}}$

Substituting the limits, we obtain

$$\text{Gross Work} = \int_0^1 \int_b^{mQ+b} \int_{(K/P)^{\frac{1}{y}}}^{(A/P)^{\frac{1}{y}}} dQ\,dP\,dV + \int_{V_c}^{V_d} P_c dV - (K/V^y)\,dV$$

Integrating and simplifying gives

$$\text{Gross Work} = (A^{\frac{1}{y}} - K^{\frac{1}{y}})/(-1/y+1)\,[(P_2^{-\frac{1}{y}+2} - P_c^{-\frac{1}{y}+2})/(-1/y+2)\,(P_2 - P_c)] + (K - A)/(y-1)\,D^{y-1}$$

where

D = cylinder volume
P_c = compression pressure
P_2 = final pressure

Since the net work equals the gross work less the pseudo-hysteresis loss,

$$\text{Net Work} = [(A^{\frac{1}{y}} - K^{\frac{1}{y}})\, y/(y-1)]\, P_2^{-\frac{1}{y}+1} + (K-A)/(y-1)\, D^{y-1} - C + [(CP_c/P_2 - P_c)(\log e \{ P_2/P_c \})]$$

Pressure-Volume and Pressure-Volume-Quantity-Card Comparison

In Fig. 2, the solid lines represent a conventional pressure-volume card, and the dotted lines represent the

Fig. 4—A Pressure-Volume-Quantity Card Showing Detonation

projection on the plane, $Q = 0$, of the corresponding pressure-volume-quantity card.

The main usefulness of the pressure-volume card, as stated previously, is as a graphical representation of the pressure applied to the top of the piston against the distance through which the piston moves, the area of which is a measure of the work delivered to the piston. On the other hand, the pressure-volume-quantity card represents the work done *by* the gases. It is evident, therefore, that the work represented by the volume of the pressure-volume-quantity card should equal the work represented by the area of the pressure-volume card. Actual calculations upon the special case diagrammatically represented in Fig. 2 give the following result per pound of mixture: Net work done by the gases as obtained from the pressure-volume-quantity card equals 146,200 ft-lb. The work delivered to the piston as represented by the area of the pressure-volume card equals 146,600 ft-lb.

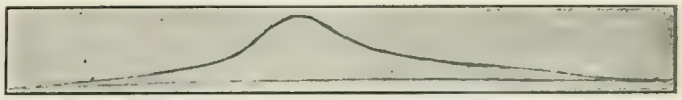

Fig. 5—Pressure-Time Card from an Engine with Normal Combustion

The slight discrepancy between the above two numerical values is representative of the approximations used in deriving the formula for net work on the pressure-volume-quantity card. It is felt that the agreement between these two numerical values is sufficiently close to justify for the present the assumptions and approximations made in this work.

The diagram in Fig. 3 shows thermal efficiencies for different compression-ratios calculated by the equations based upon the pressure-volume-quantity card. The gross as well as the net work is represented. The difference between these two curves represents the pseudo-hysteresis loss. No increase of heat loss due to higher compressions was used in these calculations; so, the increase in the pseudo-hysteresis loss indicates the increasing importance of correct thermal design in engines of higher compression-ratios. The customary efficiency curve, derived by conventional thermodynamics using $n = 1.2$, is shown also in Fig. 3.

Representation of Detonation

Although the primary purpose of this paper is not a discussion of the phenomenon of detonation, the paper would be incomplete without showing how detonation can be represented on the pressure-volume-quantity card. The pressure-volume card does not lend itself to depicting detonation because, at the time detonation occurs, the piston is approximately at top dead-center; the result is that the pressure rise in both normal combustion and detonation is represented as a single straight vertical line at one end of the card. The pressure-time card is a distinct improvement upon the pressure-volume card for studying detonation insofar as it shows a distinct difference between pressure changes in normal combustion and the rapid rise of pressure that occurs in detonating combustion. However, the pressure-time card does not convey a clear conception as to what detonation is. A pressure-volume-quantity card representing detonating combustion is shown in Fig. 4.

Referring to the formula $P_1 - P = (W^2/g)\ (V - V_1)$, it has been pointed out in this paper that the normal reaction velocity, W, is so small that the Q intercept of the combustion surface does not depart materially from a horizontal line. When detonation occurs, this is no longer true; W becomes so large that the departure of a Q intercept of the combustion surface from the horizontal must be taken into account. In fact, this intercept becomes nearly vertical instead of horizontal, as shown in the diagram in Fig. 4. This representation of detonation on the pressure-volume-quantity card is far superior to the representation on the pressure-time card. However, the pressure-time card must be relied upon for tak-

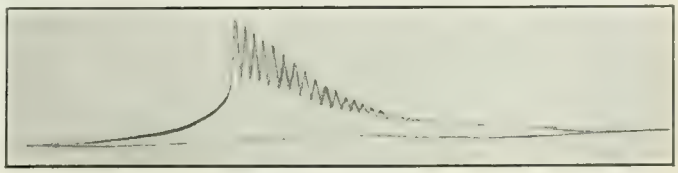

Fig. 6—Pressure-Time Card from an Engine That Was Detonating

ing data on detonation, for which purpose it is far superior to the pressure-volume card.

It is obvious that detonation, as represented on the pressure-volume-quantity card, is a localized phenomenon that only a portion of the fuel charge undergoes. Furthermore, it is obvious from the pressure-volume-quantity card that, during detonation, more mechanical work is obtained from the heat energy of the fuel than in the case of normal combustion, and yet we do not find engines that deliver more work when detonating. The explanation of this is very simple. The increased transformation of heat energy depicted on a pressure-volume-quantity card during detonation is delivered as kinetic energy. The localized pressure is a high-pressure wave that depends for its very existence upon accelerating mass-particles to its rear, and it is the kinetic energy of these mass-particles that is represented by the increased volume shown in Fig. 4. Unfortunately, our engines are not designed to take advantage of these high velocities of the mass-particles. If it were possible to have an auxiliary turbine within the cylinder-head, this kinetic energy could be put to useful work; but, as it is, this energy dissipates itself as a violent surging of the gases, and eventually becomes heat energy.

In substantiation of this explanation, Figs. 5 and 6 are included. These show two photographic pressure-time cards taken from the same engine within 2 or 3 min. of each other. In Fig. 5, the engine was operating on normal combustion. The only surging apparent is of the type normal to such combustion. Fig. 6 shows a card from the same engine when it is detonating. The violent surging shown is a clear indication of the large amount of kinetic energy liberated during detonation that could not be utilized by the piston.

Summary

The important points of this paper are summarized as follows:

(1) A diagram has been presented, which although inaccurate on account of the lack of quantitative data, is nevertheless qualitatively representative of the exact phenomenon of combustion as it occurs in the internal-combustion engine

(2) By means of this diagram, the fallacy of the conventional pressure-volume card as a basis for thermodynamic interpretation of internal combustion is shown

(3) The mechanism of an important loss that has heretofore been improperly understood, the so-called pseudo-hysteresis loss, is revealed

(4) It is shown that detonation can be represented truly upon the pressure-volume-quantity card

THE DISCUSSION

W. G. Wall:—According to the theory advanced in the paper, the expansion of certain particles produces a higher pressure and, when the knock is eliminated, a certain amount of power that would otherwise be available is lost.

Thomas Midgley, Jr.:—No. To have a high-pressure wave, there must be a high concentration of particles in the wave-front. Consequently, the remainder of the charge will have its pressure reduced slightly. However, that is not where the loss of power during knocking comes from. The loss of power is a secondary effect. During detonation, the flame-front is radiating more heat than otherwise, and it is because of this extra loss of heat to the water-jacket that we fail to get as much power out of an engine that is knocking as we do from this same engine when the knock is eliminated by the addition of an anti-knock material.

R. W. A. Brewer:—Have you satisfied yourself as to what causes the noise of detonation?

Mr. Midgley:—Dr. H. C. Dickinson explained that, at least to my entire satisfaction, when he showed that the high-pressure high-velocity wave striking the side of the cylinder-head would cause the cylinder-head to vibrate as though it had been struck with a hammer and would, consequently, give off the typical noise that we hear during detonation.

Mr. Brewer:—The thickness of the cylinder would have an effect upon the character of the sound of the knock, would it not?

Mr. Midgley:—Yes.

P. J. Dasey:—Have you made any investigation as to what effect different spark-plug positions have on detonation?

Mr. Midgley:—The spark-plug position has some effect. I cannot lay down a definite set of rules for the best location of spark-plugs. To my mind, the spark-plug position in the Knight engines seems to be ideal. This is, however, physically impossible to obtain in a valve-in-head engine.

G. T. Briggs:—Have you any definite idea as to the practical limit to which one can go in raising compressions?

Mr. Midgley:—I feel confident that a 7 to 1 compression-ratio will be very close to the practical limit in increasing compressions. We found that we gained so little in going above a ratio of 7 to 1 that it was not worth the trouble.

A Member:—How do you explain the increased tendency of kerosene to detonate, compared with gasoline?

Mr. Midgley:—We simply know that it is true. In the equation $W = KD^nT^m$, the factor K must be determined experimentally. In the paraffin series, we have satisfied ourselves that K increases with a decrease in volatility. In the case of the aromatics, K diminishes with a decrease in the volatility. How it behaves in other series of hydrocarbons, we do not know at the present time, but we are working on the problem.

Internal-Combustion Engine Characteristics Under High Compression

By J. H. Holloway,[1] H. A. Huebotter[2] and G. A. Young[3]

Annual Meeting Paper *Illustrated with* Photographs and Charts

THIS paper is a report of a series of tests conducted during the summer of 1922 by the authors at the Engineering Experiment Station of Purdue University. The work consisted of research into the operation of internal-combustion engines under comparatively high compression on ordinary gasoline without detonation. The compression-ratio of the engine was 6.75 and the compression pressure was 122 lb. per sq. in., gage. The ingoing charge was passed through a hot-spot vaporizer and thence through a cooler between the carbureter and the valves. Jacket-water temperatures between 150 and 170 deg. fahr, were carried at the outlet port of the jacket.

The theory held by the authors as to the causes of detonation of the combustible charge is presented briefly. The source of the two phases of detonation encountered in this work is believed to be overheated areas in the combustion-chamber. The methods of combating these hot spots are given in detail, and the special equipment applied to the engine to accomplish the desired result is described. The effects of load, speed, compression-ratio and mixture-ratio are studied, and curves showing the variation in the engine characteristics due to each factor are submitted. All tests were run without a trace of detonation.

The results of the work point to the following conclusions:

(1) Automobile engines designed to give a uniform cooling of the combustion-chamber walls will permit the use of much higher compression-ratios than those employed at present, with a consequent gain in engine power and economy

(2) The fuel-air ratio for maximum economy borders upon the lean limit for reliable combustion

(3) For maximum power, the mixture-ratio need not exceed 0.075 lb. of gasoline per lb. of dry air

(4) With concentrated heating of the mixture at the carbureter outlet, a local temperature of 125 deg. fahr. is sufficient to give good operation at full throttle. Cooling to 100 deg. fahr. at the valves is desirable if the compression pressure of the engine is high. At part loads, a hot-spot temperature of 175 deg. fahr., with or without intermediate cooling, will give good results with lean mixtures

THE factor that controls the thermodynamic efficiency of an internal-combustion engine is the expansion-ratio. In the standard automotive engine, this is practically equal to the compression-ratio, which determines the pressure of the charge at the time of ignition. To secure the benefits of greater expansion, therefore, the detonation that results when compression pressures are high must be eliminated.

The compression-ratio that can be used with any given fuel is limited by the tendency of the engine to detonate under certain conditions of operation. If the gain in efficiency, due to the increased expansion of the hot gases, is great enough to offset the additional expense and care required in the design, construction and maintenance of the engine to obviate detonation, it is evident that the higher compression-ratio is desirable. It is the purpose of this paper to set forth the means adopted by us to overcome detonation under high compression-pressures, to show the gain in power and economy and to present such incidental characteristics of engine performance as apply to engine and accessory design.

Detonation, as the term is applied ordinarily in internal-combustion-engine operation, is accompanied by one of two characteristic kinds of knock. The sharp metallic "ping" that is most commonly encountered in automotive engines appears to originate from too early ignition of the compressed charge. This knock, if due to excessive spark-advance, is eliminated by proper timing of the ignition. If retarding the spark produces no diminution of the knock, the preignition is probably due to some overheated spot within the combustion-chamber. We know of no means of distinguishing between these two sources of preignition except by manipulation of the spark-timing.

A second kind of detonation occurs after ignition has originated from the electric spark and is characterized by a dull, heavy thud. Such a knock is evident at times in both high and low-compression engines. It is apparently an intermediate stage between auto-ignition and normal combustion. With high compression-pressures, ignition that is timed to occur after the dead-center may be followed by this heavy thud when the engine is thoroughly heated-up. Automobile engines with the usual compression-ratio show the same trait, when the spark is retarded after a period of preignition, due to an early spark or to excessive carbon deposit. One form of detonation may merge into the other or may disappear entirely, depending upon the condition of normal engine operation. Sufficient spark-lag will eliminate the heavy pounding, but at the expense of both power and economy.

The following theory seems to offer a reasonable explanation of this second phenomenon. The charge is ignited by the spark and burns at a normal rate of flame propagation during the early stages of the reaction. The unburned gas, which has been heated during the compression stroke, is compressed still further by the expansion of the products of combustion behind the flame-cap. Unless the heat due to this latter compression is transferred to the combustion-chamber walls as rapidly as it is generated, the temperature of the entire mass of the gas rises to the ignition point and explodes instantaneously, producing a hammer-blow effect in both shock

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and sound. In support of this hypothesis is the experimental evidence that the knock ceases when certain suspected high-temperature areas are subjected to additional cooling. The absorption of heat from the combustible charge is thereby facilitated and auto-ignition is prevented.

The foregoing description and explanation of the two types of detonation point to the following sources as being most open to suspicion. Preignition due to auto-ignition before the passage of the spark may originate from an excessive temperature of either the spark-plug core or electrodes, the exhaust-valve, the center of the piston-head or from any other point in the combustion-chamber that is not cooled sufficiently. Detonation that follows normal ignition may be due to any of the above sources except the first. Hence, careful attention to the cooling of the entire combustion-chamber is essential to the suppression of detonation.

In addition to the elimination of hot-spot areas, it is advisable to maintain a low entrance-temperature of the fuel-air mixture. The temperature of the compressed charge must never exceed the ignition point of the fuel before the passage of the spark and, to prevent the charge from being overheated by compression in the cylinder, the initial charge-temperature must be reduced to the minimum consistent with uniform distribution to secure the thermal advantages of a high compression-ratio.

High-Compression Engine Performance Tests

With this conception of the benefits and the detriments inherent in a high compression-ratio, a series of tests was planned to study engine performance under high compression. The objects of the tests were: (*a*) to determine roughly the maximum compression-pressure an automobile engine can carry on standard gasoline under a representative range of operating conditions without detonation, and (*b*) to study the characteristics of the engine when so modified. The difficulties encountered in securing satisfactory operation, the methods used in overcoming them and the reasons for the adoption of these methods are presented herewith.

A compression pressure of 150 lb. per sq. in. was employed at first to accentuate the detonation and to facilitate the location of the sources. Two engines of different types were used in the work. Beginning with engines that were standard in all respects with the exception of the cylinder-head, the load was gradually increased until detonation became apparent. The cylinders in which the knock occurred were studied with reference to the probable factors inducing detonation. These factors were eliminated gradually until the engine operated satisfactorily under all normal conditions encountered on the dynamometer.

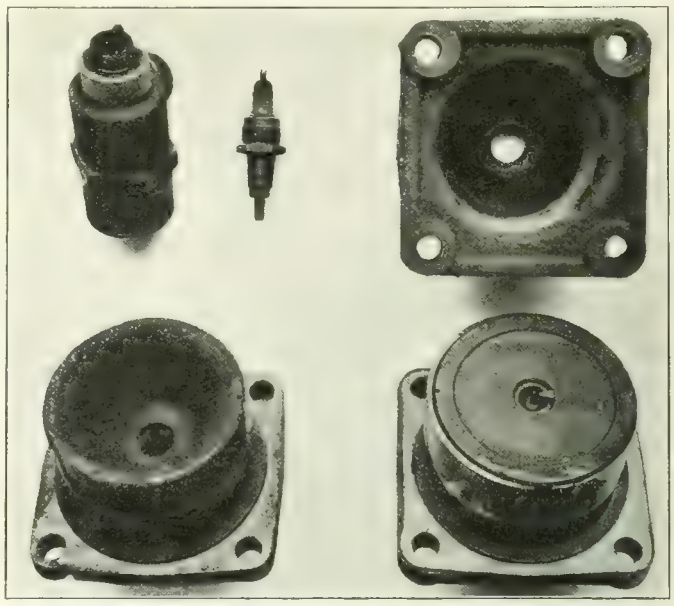


Fig. 2—Special Cylinder Head Equipment Used in Connection with the Tests

Experiments on a six-cylinder poppet-valve engine showed that spark-plugs with porcelain cores and small electrodes were the first sources of preignition. Mica cores with heavy electrodes and water-jacketed shells were required to maintain a practical working temperature of the plug and, in redesigning the second engine,

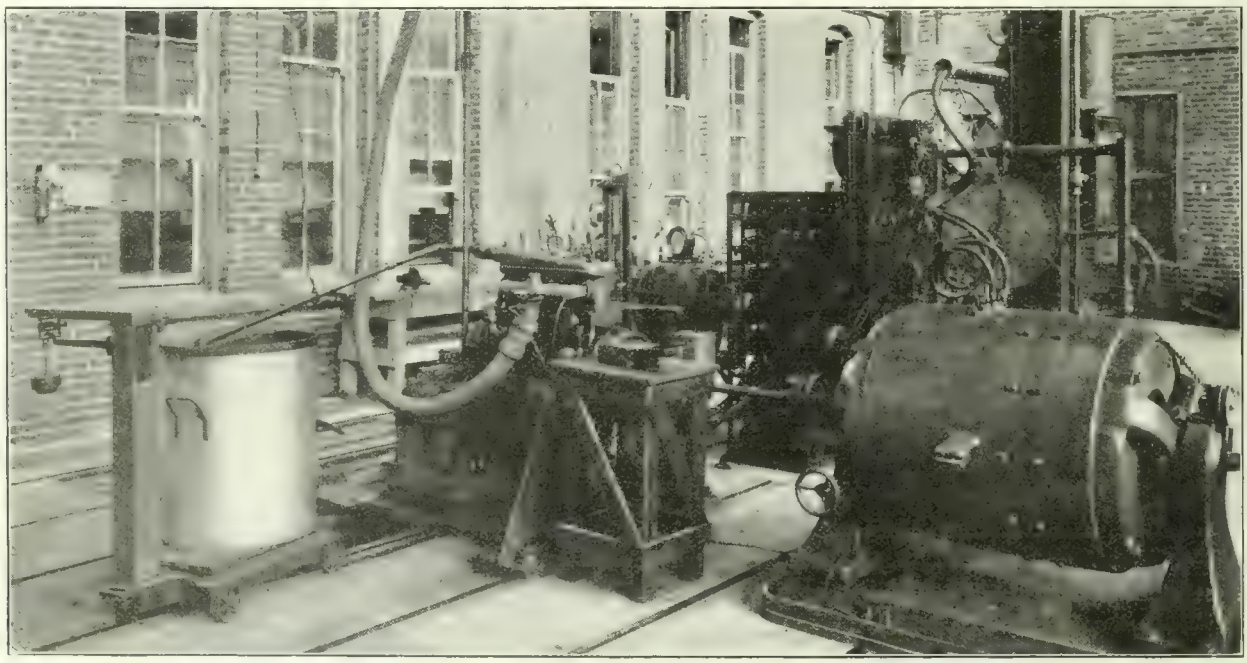


Fig. 1—View of the Laboratory Showing the Engine on Which the Tests Were Conducted

this type of plug was incorporated in its cylinder-heads.

After the spark-plug trouble was overcome in the poppet-valve engine, the exhaust-valves showed unmistakable signs of overheating. In the two cylinders that detonated first, the exhaust-valve seats were not completely water-jacketed and could be cooled sufficiently to eliminate preignition only with a water-outlet temperature below 100 deg. fahr. This engine was not a good example of modern poppet-valve design. Trouble from overheated valves was eliminated by changing to a sleeve-valve type of engine on which all further investigation was conducted.

On this four-cylinder engine cylinders Nos. 1 and 4 detonated severely, while Nos. 2 and 3 operated normally. Three possible causes for this effect were considered: (*a*)

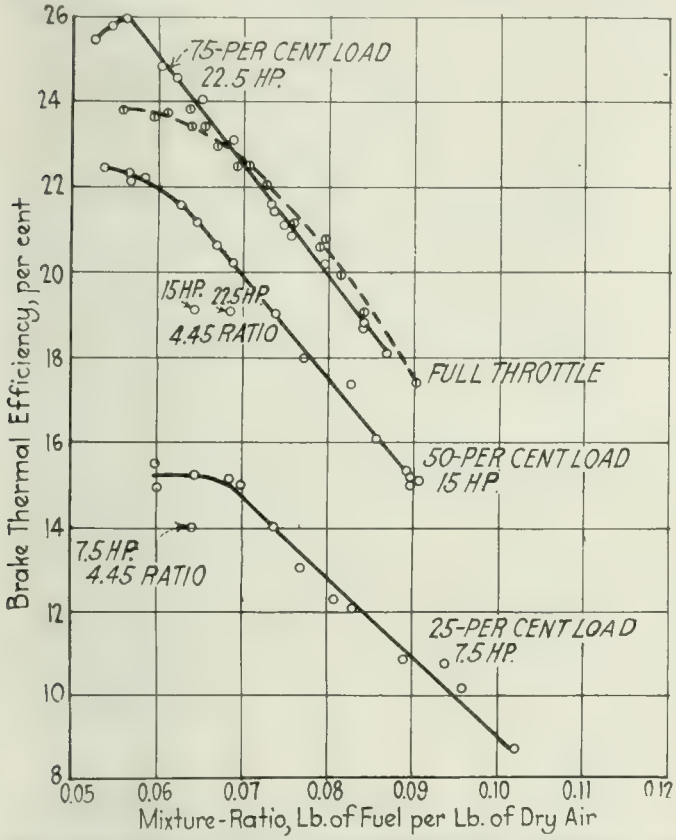


FIG. 3—CURVES SHOWING THE BRAKE THERMAL EFFICIENCY FOR VARIOUS MIXTURE-RATIOS THROUGHOUT THE FULL RANGE OF LOAD

restricted or sluggish circulation of the cooling water at the front and the rear of the water-jacket; (*b*) unequal distribution of the fuel in the charge; and (*c*) arrested scavenging of the center cylinders.

The water-jacket was designed for thermo-syphon circulation with the inlet port between the two center cylinders. In the tests the water was forced through the jacket under pressure from the city supply, which change may have disturbed the uniformity of distribution obtainable with the original system. The single inlet-pipe was replaced by a water manifold with an individual lead to each cylinder to insure more nearly equal cooling. The improvement resulting from this alteration was slight, but the manifold was retained as a safety measure.

The carbureter was at first bolted directly to the cylinder block at the entrance to the water-jacketed inlet-manifold. In this arrangement, good vaporization and distribution were impossible with the gasoline in current use, and a hot-spot vaporizer was therefore placed at the carbureter outlet. The high temperature of the mixture

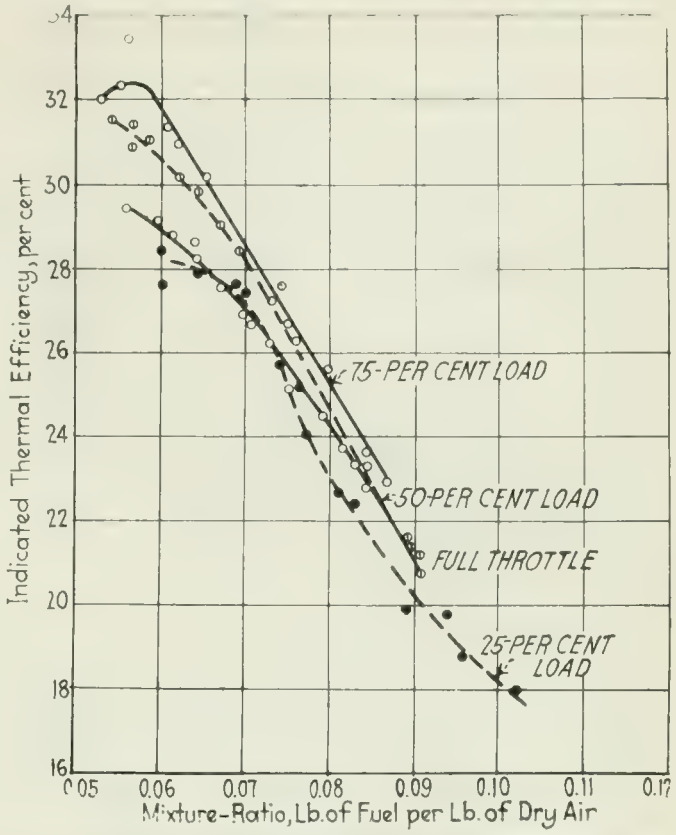

75-PER CENT LOAD
50-PER CENT LOAD
FULL THROTTLE
25-PER CENT LOAD
Indicated Thermal Efficiency, per cent
Mixture-Ratio, Lb. of Fuel per Lb. of Dry Air

FIG. 4—INDICATED THERMAL EFFICIENCY AT DIFFERENT MIXTURE-RATIOS THROUGHOUT THE FULL RANGE OF LOAD

required to secure vaporization of the fuel promoted detonation, and consequently an intercooler was used to lower the temperature of the charge at the valves. The carbureter and the hot-spot were dropped about 24 in. below the inlet-manifold, and a vertical water-jacketed pipe was inserted as a means of cooling the mixture of air and vaporized fuel without causing condensation. The device produced a drop in temperature of about 30 deg. fahr. from an initial temperature of 125 deg. fahr. that previously had been found necessary for good distribution with this vaporizer. The change in the carburetion system permitted the use of higher temperatures at the carbureter outlet and in that way simplified the distribution problem. It was not possible to detect any difference in starting with this lowering of the carbureter position. Cylinders Nos. 1 and 4 continued to detonate before Nos. 2 and 3, although not to such a marked degree. The matter of more thorough scavenging of the center cylinders was not followed-up.

In an engine with suitable spark-plugs and effective

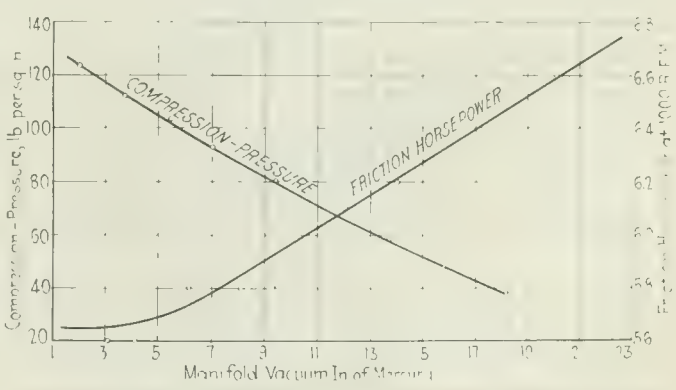


FIG. 5 FRICTION HORSEPOWER AND COMPRESSION-PRESSURE CURVES

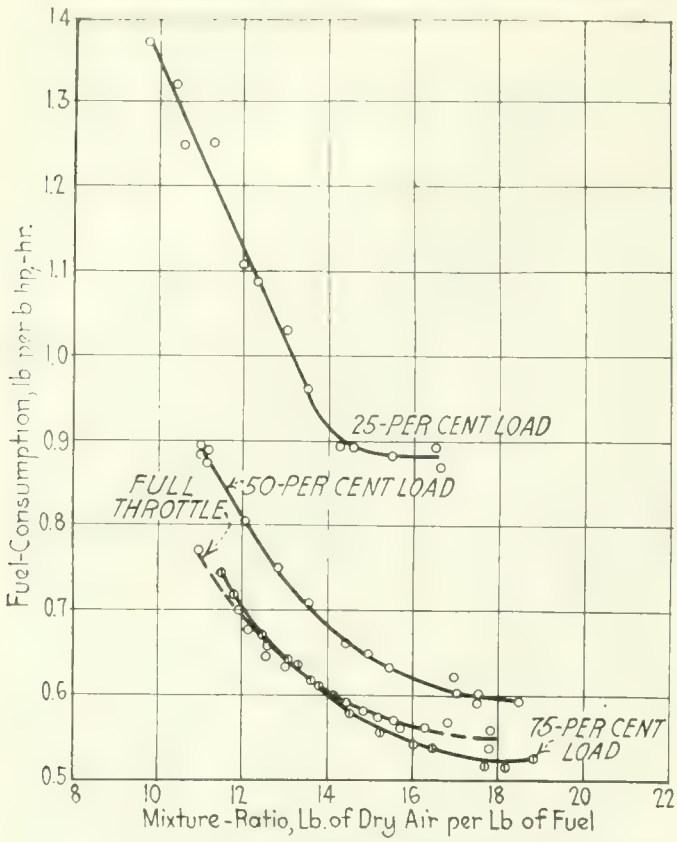

Fuel-Consumption, lb per b hp-hr
Mixture-Ratio, Lb. of Dry Air per Lb of Fuel
25-PER CENT LOAD
50-PER CENT LOAD
FULL THROTTLE
75-PER CENT LOAD

FIG. 6—SPECIFIC FUEL-CONSUMPTION AT DIFFERENT MIXTURE-RATIOS THROUGHOUT THE FULL RANGE OF LOAD

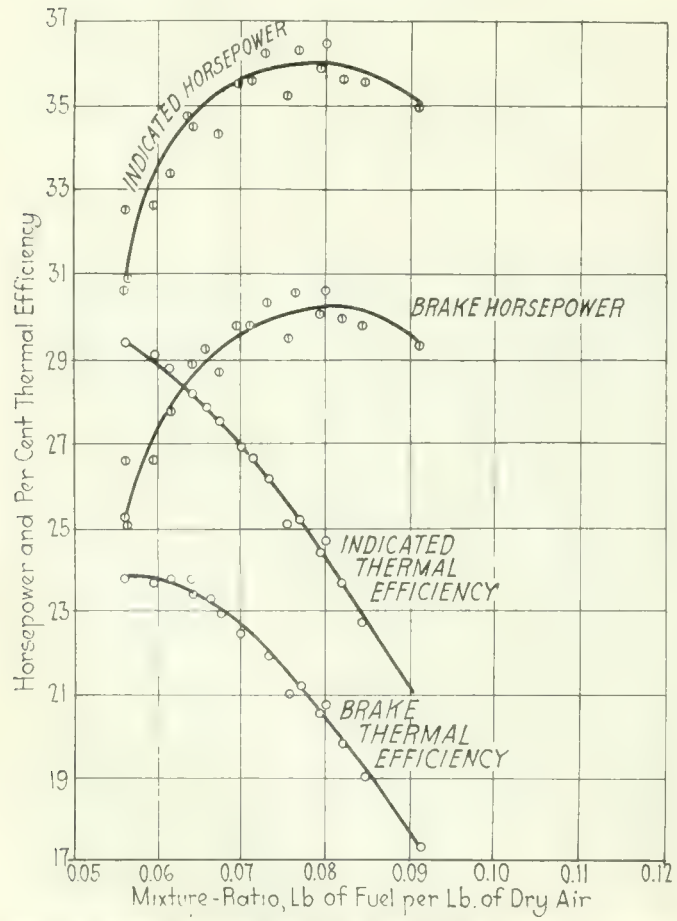

Horsepower and Per Cent Thermal Efficiency
Mixture-Ratio, Lb of Fuel per Lb. of Dry Air
INDICATED HORSEPOWER
BRAKE HORSEPOWER
INDICATED THERMAL EFFICIENCY
BRAKE THERMAL EFFICIENCY

FIG. 7—CURVES SHOWING THE VARIATION IN THE HORSEPOWER AND THERMAL EFFICIENCY AT FULL THROTTLE

cooling of the water-jacketed walls of the combustion-chamber, the temperature of the piston-head is the deciding factor in limiting the compression pressure. This surface, being most distant from the origin of combustion, is in the best possible position to detonate the final portion of the charge ahead of the flame-front. On account of their higher conductivity, aluminum pistons remain cooler than gray-iron pistons, and hence reduce the tendency of the engine to detonate. The original gray-iron pistons were therefore replaced by aluminum pistons that were of substantially the same design.

The breaker of the battery system, with which the engine was originally equipped, failed under the high primary voltage found necessary to assure reliable ignition with high compression at full throttle. This difficulty was overcome by the substitution of a high-tension magneto.

The salient features in the engine that permitted the carrying of high compression under all conditions of operation were

(1) Effectively cooled spark-plugs
(2) Comparatively cool exhaust-valves
(3) Uniform circulation in the water-jacket
(4) A carburetion system that gave good distribution with low mixture-temperatures
(5) Aluminum-alloy pistons
(6) An ignition system capable of producing an adequate spark under high compression

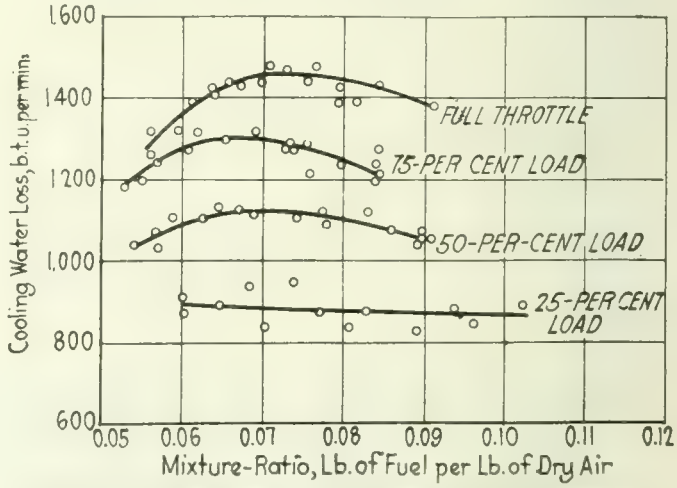

Cooling Water Loss, b.t.u. per min.
Mixture-Ratio, Lb. of Fuel per Lb. of Dry Air
FULL THROTTLE
75-PER CENT LOAD
50-PER-CENT LOAD
25-PER CENT LOAD

FIG. 8—THE HEAT-LOSS TO THE WATER-JACKET AT DIFFERENT MIXTURE-RATIOS

EQUIPMENT AND APPARATUS

The second engine used for this high-compression investigation was a Model 88-4 Willys-Knight of 4⅛-in. bore and 4½-in. stroke, shown in Fig. 1, and slightly modified to adapt it to the abnormal conditions under which it was to operate. As a result of the preliminary work tending toward the suppression of detonation, a compression pressure of 122 lb. per sq. in. was chosen as being the highest practicable for ordinary gasoline. The special heads used in the test to secure this pressure had a compression-ratio of 6.75, as compared with 4.45 in the standard heads and are illustrated in Fig. 2.

A set of standard Willys-Knight aluminum-alloy pistons was substituted for the gray-iron pistons before the tests recorded herewith were carried out. This permitted a greater spark-advance than was possible with the original pistons. Special spark-plugs with shells in direct contact with the cooling water formed the central portion of the high-compression heads and acted as anchorages

for the standard demountable water-jacket cover. A Model SS-4 Splitdorf magneto was installed in place of the battery system. The spark-advance was measured on a graduated sector at the magneto-control lever.

A Model LB-2 Stromberg carbureter was used in connection with a hot-spot vaporizer and a long vertical external inlet-pipe. The vaporizer was heated in such a way as to permit control of the mixture temperature at the entrance to the manifold independently of the engine. After being heated to the point beyond which previous tests had shown no gain in economy was secured, the mixture was cooled in the vertical extension of the manifold. The benefit of this lowered temperature was partly lost by the reheating in the main inlet-manifold, which was surrounded and heated by the jacket water of the cylinder block.

A Sprague electric dynamometer was used to measure the brake and the friction horsepower in the usual manner. The fuel consumed per test was weighed on a beam balance sensitive to 0.01 oz. The air was measured in an Emco No. 4 meter. The inlet-manifold vacuum was determined by a mercury-column gage connected to the manifold between cylinders Nos. 1 and 2. Exhaust temperatures were measured by thermocouples at the No. 4 exhaust-port and at the end of the manifold. Thermometers were inserted at the inlet and the outlet of the water-jacket, at the outlet of the fuel vaporizer, at the top of the manifold water-jacket and at the No. 4 inlet-port. The humidity of the atmosphere was measured by a wet-and-dry-bulb hygrometer. The cooling water for each test was caught in a tank and weighed on a platform scale. Compression pressures were determined with a compressometer consisting of a pressure gage in combination with a chamber and check-valve that screwed into the spark-plug shell.

Test Procedure

Investigations were made to establish the effects of the following four factors in engine characteristics:

(1) Load
(2) Mixture-ratio
(3) Speed

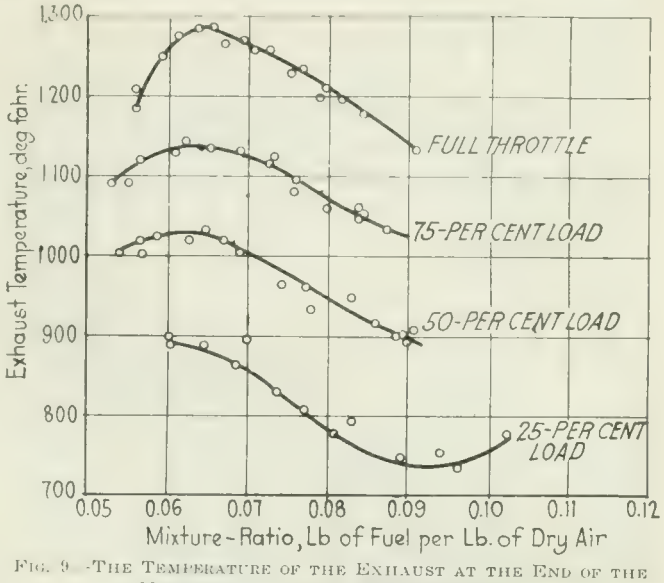


Fig. 9.—The Temperature of the Exhaust at the End of the Manifold at Various Mixture-Ratios

(4) Gain in power and economy due to the increase in the compression-ratio

The first two factors were studied at a constant engine-speed of 100 r.p.m. Tests were run under a constant load at approximately 25, 50 and 75 per cent of the maximum power, with various mixture-ratios ranging from the leanest at which the engine would fire regularly to that which showed sluggish combustion. The throttle opening was changed as required to maintain a constant load and speed. Similar tests were run at full throttle and a constant speed with a change in the load as the mixture-ratio changed.

Two series of runs were made with a fixed carbureter-adjustment and at speeds varying from 500 to 1300 r.p.m. In one run, a constant dynamometer-load of 15 lb. was maintained; in the other, the throttle was fully opened.

In all of these tests the spark was adjusted for the maximum power, and the mixture temperature at the hot-spot was held at the point that gave a uniform distribu-

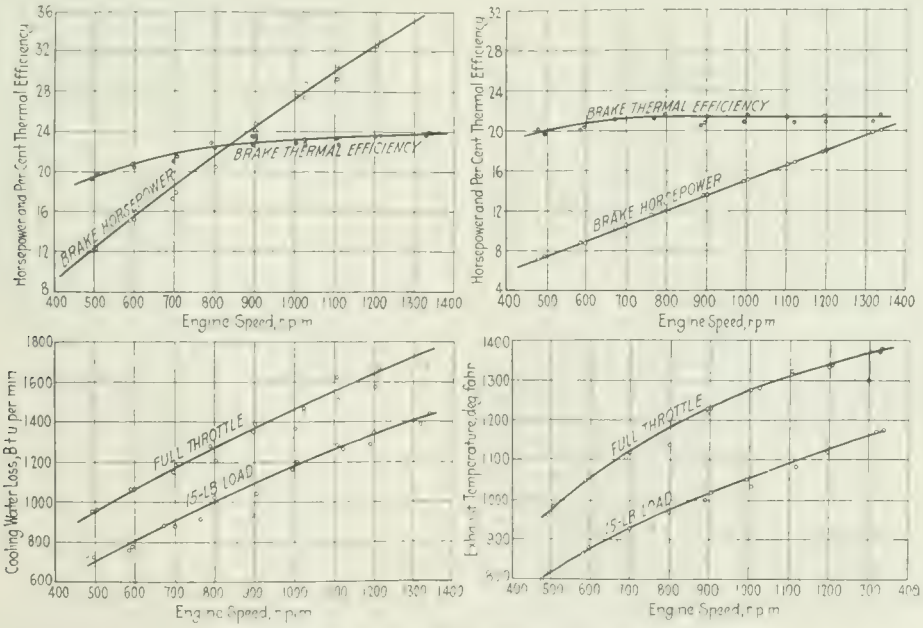


Fig. 10—Curves of Test Results at Different Speeds

Brake Horsepower and Thermal Efficiency at Full Throttle
Heat-Loss to Water-Jacket

Brake Horsepower and Thermal Efficiency at 15-Per Cent Brake Load
Temperature of Total Exhaust

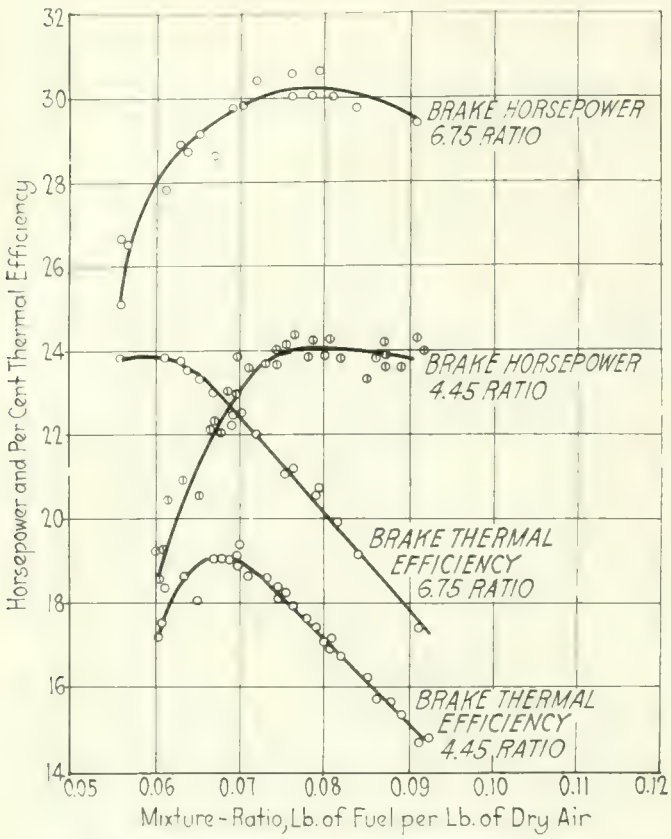


Fig. 11 Full-Load Performance with High and Low Compressions

tion without excessive loss in volumetric efficiency. Between the hot-spot and the valves, the maximum cooling of the mixture that was consistent with good operation of the engine was sought. The temperature of the jacket outlet-water was held between 150 and 170 deg. fahr. as nearly as possible, with little adjustment of the flow rate except in the case of the speed series. Fuel, air, cooling water and exhaust temperatures were taken at the points previously described; and load, revolutions per test and time per test were recorded.

The comparative power and brake thermal-efficiency of the 6.75 over the 4.45-compression-ratio are based upon the full-throttle mixture-run at 1000 r.p.m., and data derived from somewhat similar tests on the same engine by O. C. Berry and C. S. Kegerreis, of the Purdue Engineering Experiment Station, in connection with carburetion research. The power curve is taken from Fig. 28 of a bulletin on the Carburetion of Gasoline.[4] The thermal-efficiency curve is changed slightly to correspond with the fuel value assumed in the current tests.

Results of Tests

The results of the tests are presented graphically in Figs. 3 to 11. The brake thermal-efficiency for the full range of the load and the mixture-ratio at 1000 r.p.m. is shown in Fig. 3, and the corresponding indicated thermal-efficiency in Fig. 4. The thermal efficiency is based upon a lower fuel-value of 18,900 B.t.u. per lb., and the indicated horsepower under the several loads is taken as the sum of the brake and friction horsepower of Fig. 5. The fuel-consumption per brake horsepower-hour is plotted in Fig. 6 and conveys the same information as Fig. 3 in different terms. The variation of both the power and the thermal efficiency with a change in the mixture-ratio at full throttle is illustrated in Fig. 7. Incidental data showing the heat-loss to the water-jacket and the temperature of the exhaust at the end of the manifold with different mixture-ratios appear in Figs. 8 and 9 respectively.

The influence of the speed upon the brake horsepower, the brake thermal-efficiency, the radiation loss and the exhaust temperature at full load and at approximately half load, are covered in Fig. 10. The carbureter adjustment was not changed during the speed tests and the variation in the mixture-ratio, 0.062 to 0.071, was merely that inherent in the carbureter design under changes in the speed and the load.

A comparison of the power and the thermal efficiency at full throttle with compression-ratios of 4.45 and 6.75 is made in Fig. 11. In Fig. 3 three points taken from the bulletin on the Carburetion of Gasoline[4] are spotted, which indicate the improvement in economy through the full range of engine power.

In the load tests at 1000 r.p.m., the spark-advance was 5 deg. at full load, 12 deg. at 75-per cent load, and 20 deg. at 50 and 25-per cent load. During the full-load speed-tests, the spark-advance varied from 0 to 10 deg. between the speeds of 500 and 1300 r.p.m. At one-half load, the spark lead ranged from 10 to 20 deg. for the same speed variation. No detonation was audible during any of these tests.

Conclusions

From these tests, which are represented as covering only a narrow range in the field of gasoline-engine operation, the following conclusions are drawn:

(1) Under laboratory conditions, a compression pressure of 120 lb. per sq. in. gage is perfectly feasible when the engine is designed with a full regard for the elimination of the factors that induce detonation

(2) Under service conditions, the same attention to these factors will permit the use of much higher pressures than those common at present

(3) An increase in the compression-ratio results in a marked improvement in the thermal efficiency and the general performance of the engine at all loads and in the maximum power at all speeds

(4) The sources of detonation are the spark-plug, the exhaust-valve, the piston-head and any other portions of the combustion-chamber walls that become overheated

(5) The maximum economy is obtained with the leanest fuel-air mixture giving reliable combustion. Such a mixture varies from 0.060 lb. of fuel per lb. of dry air at 25-per cent load, to 0.057 lb. at 75-per cent load; or, from 16.6 to 17.5 lb. of dry air per lb. of fuel. Hence, for this range of load, the leanest possible mixture is desirable, provided good vaporization is secured. At a full throttle-opening, the maximum power is usually sought at the expense of economy. An 0.075 mixture, or 13.3 lb. of air per lb. of fuel, is rich enough to insure the greatest output

(6) The water-jacket heat-loss reaches its maximum value at approximately the mixture giving the highest power with a fixed throttle-opening, or a 0.075 ratio

(7) The exhaust temperature is highest with a 0.065 ratio

(8) The power of an engine can be increased 25 per cent by a change in the compression ratio from 4.45 to 6.75, provided detonation is absent

(9) With the same change in the compression-ratio,

[4] See Purdue University Engineering Experiment Station Bulletin No. ...

the thermal efficiency is raised 7 to 12 per cent through a load range of 25 to 100 per cent of the engine power

(10) At full load, a mixture temperature of 125 deg. fahr. at the hot-spot is high enough to give good distribution in a four-cylinder engine with a properly designed hot-spot. If the mixture is cooled below this temperature between the hot-spot and the valves, the performance of the engine is improved. A low limit of 100 deg. fahr. at the valves can be allowed safely.

(11) At partial throttle-opening, a hot-spot temperature of 175 deg. fahr. is not excessive and assists in the use of very lean mixtures for high economy

This investigation is being continued, and it is expected that the final results will be published in a bulletin of the Engineering Experiment Station of Purdue University.

IMPACT TESTING

THE impact test has been used as an acceptance test in certain European specifications. It is not generally adopted in this Country. A committee of the American Society for Testing Materials is working on some form of test suitable for the United States requirements.

The Fremont test requires a test-specimen 30 mm. (1.1811 in.) long with a cross-section of 8 x 10 mm. (0.3150 x 0.3937 in.). It is notched on the broad side 1 mm. (0.0394 in.) deep and 1 mm. (0.0394 in.) wide. The test-piece is laid on supports 21 mm. (0.8268 in.) apart with the notch on the under side and struck a blow with a falling tup midway between the supports. The difference between the energy before and after the fracture gives the amount of energy necessary for fracturing the test-specimen. The weight of the tup, which falls from a height of 4 m. (13.1233 ft.) is 10 or 15 kg. (22.0462 or 33.0693 lb.). A machine of this kind requires considerable height above the floor level, but possesses the advantage of having a high speed of impact.

The Charpy test requires a test-specimen 55 mm. (2.1654 in.) long with a cross-section of 10 x 10 mm. (0.3937 in.). It is notched in the center by drilling a 1.3-mm. (0.0502-in.) hole so that the bottom of the hole is 5 mm. (0.1969 in.) from the edge. The notch is completed by running a 1-mm. (0.0394-in.) slot into the hole. This test-piece is supported horizontally between 40-mm. (1.5748-in.) abutments and is struck by a swinging pendulum at the middle of its length on the side opposite the notch. The energy absorbed in making the fracture is determined from the residual energy after fracture. The weight of the tup is 32.5 kg. (71.6503 lb.). It will be noted that the machining of a notch of this nature requires at least two operations and it is probably difficult to reproduce accurately on hard materials. The difficulty of obtaining notch uniformity is, of course, more or less inherent in all impact tests, but is probably more pronounced in this case.

The Izod test requires a test-specimen 75 mm. (2.9528 in.) long with a cross-section of 10 x 10 mm. (0.3937 in.). It has a transverse 45-deg. angle, V-shaped notch 2 mm. (0.0787 in.) deep; the radius at the root of the notch being 0.25 mm. (0.0098 in.). The piece is held vertically in a vise with the lower edge of the notch at the same level as the vise edge and is broken by a swinging tup striking the test-piece on the notched side but above it. As before, the residual energy deducted from the striking energy gives the energy required for fracturing the test-piece. This energy is usually indicated on a scale by a pointer actuated by the swinging pendulum.

The Stanton test requires a test-specimen about 6.00 in. long having a 0.50-in. diameter. It has a groove cut at the center, 0.05 in. deep and 0.05 in. wide. This test-piece is held horizontally in supports 4.50 in. apart and is rotated 180 deg. between successive blows which are struck over the groove by a falling tup. The weight of this hammer, or tup, is 4.70 lb. and the height of the fall is adjustable. The number of blows required to fracture the test-specimen is recorded.

The Brinell test has often been put forward as a test in itself. It was never intended for such a use. It has a value only as related to some fundamental test such as the tensile test. It seems that this cannot be emphasized too strongly. There is some definite relation between the tensile-strength and the Brinell hardness for a given material. Similarly, attempts have been made in the past to correlate impact values and fatigue limits, yet this seems erroneous since the conditions of fracture have nothing in common. The fatigue fracture is determined by a series of slips in the material itself, while the impact fracture is propagated by a notch definitely located in the specimen. The fact, therefore, remains that a material giving a low impact-figure may not show a low fatigue-limit, but it is still relevant to state that the former material is in a notch-brittle condition.

Therefore, although it is difficult and dangerous to make definite statements in favor of any particular test the following conclusions seem to be warranted:

(1) The impact test of the Izod type is one of the most sensitive mechanical tests so far introduced to determine the design of heat-treatment given to a material

(2) This impact test shows characteristics in certain materials that the tensile tests do not indicate

(3) The impact test corresponds, along with other physical properties such as reduction of area, to the variation in heat-treatment and is therefore valuable for confirmatory purposes

(4) The impact test offers valuable evidence through observation of the fracture, relative to the thermal treatment that the material has received

Any test that brings out something new or confirms some value already known is valuable. Provided this impact-figure is not purchased at too high a price with respect to the ultimate-strength or elastic-limit, such tests have a very great value indeed.

With regard to the repeated impact, such as the Stanton, the case is somewhat different. This test is in the nature of a fatigue test and may be closely related to the fatigue limits as determined by standard machines. This is a contention, however, which has yet to be proved.—From a paper presented by J. M. Lessells before the Pittsburgh Section of the American Society for Steel Treating.

Petroleum and Automotive Engineers Discuss Common Problems

THE subject of the Thursday session of the third annual meeting of the American Petroleum Institute held at St. Louis, Dec. 5 to 9, was, *What Is Good Gasoline?* This session was arranged to afford a common meeting-ground for discussion of the fuel problem by petroleum producers and automotive engineers. In this respect it was like similar sessions held at the City of Washington 2 years ago and at Chicago a year ago. But this is almost the extent of the resemblance. Two years ago, there was no real common meeting-ground for the two groups of engineers. Though both were willing to work together on problems of mutual interest, they had no common language. A year ago, there was a much better understanding than theretofore and the foundation was laid for the joint research that formed the main topic of this year's session.

The outstanding feature of the day's meeting was the manner in which engineers from both industries discussed the fuel problem, each with a real understanding of the problems of the other. The joint research which has brought together prominent automotive and petroleum engineers on the steering committee, even if it had accomplished nothing else, has had its effect in destroying the barrier of misunderstanding that has so long prevented harmonious cooperative action on problems where mutual interests demanded joint action. But much more than this has been accomplished, as was brought out in the various papers reviewed below.

Gasoline Specifications

Another point of especial interest which was touched on by more than one of the petroleum engineers is that of the standardization of fuel quality. A standard for quality of gasoline is obviously difficult to realize; and the more the question is studied, the more difficult, in some respects, it appears to be. Hence, the petroleum industry has long opposed the adoption of such standards for very important reasons. Nevertheless, the advantages that would accrue to both industries through a uniformity of the product, particularly if the quality were properly regulated with reference to the average temperature, are so great that at least some of the prominent petroleum engineers are beginning to believe with the automotive engineers that some degree of beneficial standardization can be accomplished.

Knock Suppressors

The first paper on the program, entitled Demonstration of the Relationship of the Knock to the Gasoline Problem, and the Remedy for the Knock, was by Thomas Midgley, Jr., of the General Motors Research Corporation. Mr. Midgley described the action of the cylinder of a four-cycle engine by a demonstration model, illustrating the normal burning of the fuel and the abnormal combustion that is accompanied by the knock. He then explained the nature of the combustion phenomena as they are understood at present, and discussed the effect of the various substances which tend to suppress the knock. This was followed by a most interesting and convincing demonstration of the action of some of these knock suppressers, first in a glass tube in which was fired a mixture of acetylene and air, alternately with and without the suppressing substance, in this case diethyl telluride; and then in a Delcolite engine that was operated alternately with two samples of the same fuel, to one of which had been added a small amount of tetraethyl lead. The results in both cases were strikingly evident. In the engine demonstration he used a knock-indicator that permits the accurate quantitative measurement of the amount of knock and serves as a basis for comparison of different fuels and anti-knock dopes. This paper has been published under the title, The Chemical Control of Gaseous Detonation with Particular Reference to the Internal-Combustion Engine.[1]

The main topic of the session was introduced when Dr. S. W. Stratton, director of the Bureau of Standards, talked on The Answer So Far Given by the Joint Research Program of the Bureau of Standards and the Oil and the Automotive Industries. Dr. Stratton prefaced his report of the Bureau's research work by some pertinent remarks on the relation of research to the two industries. Not long ago the research man was looked upon as a dreamer. The present attitude of leaders of the petroleum industry is in marked contrast to this, partly as a result of recent accomplishments along research lines. It is significant that two great industries have combined in the solving of a joint research problem.

The Public and the Government

Scientists are just beginning to learn the value of combination of research facilities. For instance, the ability of the Bureau of Standards to take up the present fuel-program is due to the fact that the training of a staff of men in heat and temperature measurement was begun 20 years ago. Ten years ago this staff undertook the solution of some of the most difficult problems of the refrigerating industry, namely, the physical properties of refrigerants; at the beginning of the war part of this staff was set to work on the problems of the aircraft powerplant; and the same staff is now engaged in the present fuel-research. Without the building up of this staff through years of development, the present progress would have been impossible.

Another point that Dr. Stratton stressed was the relation between the industries and the various Government bureaus devoted to the public good. Formerly, there was much criticism of the activities of some of these Government institutions. It should be remembered that they are acting under laws passed by our own representatives. If the laws are not good, we must look to the representatives and not to the Government bureaus. But this sort of criticism is mostly a thing of the past. Industries no longer take the attitude that it is not well for the Government to know too many things. We must remember that Government bureaus are there for the use of the industry. They can be best used by looking upon them as the laboratories of the industry. The adoption of this point of view represents one of the most important changes that has taken place between the public and the Government.

Dr. Stratton then explained the conditions leading to the undertaking of this joint research by the Bureau of

[1] See the *Journal of Industrial and Engineering Chemistry*, October, 1922, p. 894.

Standards, and described the methods employed, giving a brief summary of the results obtained so far. As this material will be presented in full at the meeting of the Society to be held this month and published in a later issue of THE JOURNAL, it will not be reviewed here. The outstanding facts, however, are that four selected grades of fuel differing in volatility were very carefully studied under summer conditions in four models of passenger car, and the results showed no significant difference in fuel mileage. Special runs to determine crankcase-oil dilution showed much more dilution with the heavier fuels. A supplementary research covering low-temperature operation is in progress, the engine under test being enclosed in a refrigerating chamber where the temperature of the air and the jacket water can be kept as low as desired. Dr. Stratton then showed a few views of the buildings of the Bureau and described briefly some of the lines of industrial research undertaken by the various divisions.

R. E. Carlson, of the Bureau of Standards, who has had charge of the experimental work, explained more in detail the experimental procedure followed in the summer program, and described the equipment which has been completed for the preliminary study of the behavior of the fuels at low temperatures.

Low-Temperature Operation

An engine has been mounted in one of the altitude test chambers of the Bureau of Standards, where the air and jacket temperature can be reduced to about 20 deg. below zero, and kept under control. The engine is coupled to a dynamometer outside the chamber, to control the load and speed. By using this method it is possible to make all the measurements made in the road tests and some others. Preliminary results have already been secured with this equipment and the work should be well toward completion by the time of the meeting to be held this month, when results to that date will be reported in full.

The next speaker was B. B. Bachman, of the Autocar Co., president of the Society of Automotive Engineers. He expressed the appreciation of the Society for the inauguration of this research and for the results obtained to date. For several years engineers have conducted individually experiments along these lines, but the results have been of little value because nothing has been done to assemble or coordinate them. Now the services of the most competent laboratory have been secured, and the results of many researches of incalculable value to the industry have already been secured.

Two phases of the problem are efficiency, or miles per gallon, and crankcase-oil dilution. No difference in consumption was shown by the summer test, but it is not safe to conclude that this is true in cold weather. The crankcase-dilution figures are not very conclusive, but show increases for the heavier fuels. Possibly dilution of oil on the cylinder-walls is more important than the crankcase dilution which results from it. Different models may show very different results in this respect.

Logical conclusions to be drawn are

(1) Many types of car, even cars several years old, could operate on fuel of grade *C* in summer weather. It is doubtful if grade-*D* fuel could be used with satisfactory results

(2) Seasonal variation of gasoline volatility and distribution with reference to climate would be a means of securing better utilization of the Country's fuel resources

J. T. B. Bowles, of the Tide Water Oil Co., said that the automotive engineers have complained for several years about the quality of gasoline and concluded that the refiners were not carrying on a research for its improvement. He maintained that the automotive industry had done nothing systematic to improve its own product. The joint program under discussion, which is in the hands of a neutral party, is the correct answer to these criticisms. Neither industry alone could have put over the results of tests of its own. The petroleum industry is bending all its energies to the production of acceptable fuels in sufficient quantity, but economic laws, rather than the industry, have control of the situation.

The results, so far, indicate that much higher end-point fuels can be used, even fuel *D* showing equal performance in mileage in some cases. Crankcase-dilution is the outstanding difficulty. A study of fuels having a greater percentage off at 212 deg. fahr. should be made, as it may remedy the starting and crankcase-dilution difficulties. The two industries and the general public have already benefited greatly by the results of the work of the Bureau of Standards.

Roger Chew, of the Standard Oil Co. of New Jersey, said that probably there have been as many theories as to what constitutes good gasoline as there are chemists in the petroleum industry. But extensive tests of long duration in the most diversified equipment are necessary before an answer can be attempted.

The Government specification known as Navy gasoline was the result of cooperation between the petroleum industry and the Government Interdepartmental Committee on Petroleum Specifications in meeting the demands during the war. This gasoline has proved very satisfactory, and it would be a benefit to the automotive industry if engineers could design for such a standard fuel. Unfortunately, refiners have marketed fuels both more and less volatile.

After stating the opinion that the minor questions as to chemical purity are being taken care of by the interested parties, and that the cooperative tests by the Bureau of Standards will go far in determining what the volatility should be, Mr. Chew closed his remarks with the following expression of opinion:

> A standard gasoline specification has distinct advantage in that it is in the direction of conservation, encourages the stabilization of the gasoline supply, tends toward efficiency of the engine builder, and last, but by no means least, would give as near as is humanly possible, complete satisfaction to the consumer.

Engine Factors

H. M. Crane, chairman of the Society's Research Committee, said in part:

> In the automotive industry, we have been fighting two factors in our engines, in connection with fuel. One is, to get the fuel vaporized before we attempt to ignite it. The other is to get the maximum economy that can be obtained only by using high compression-pressures. Mr. Midgley's organization was one of the first in the automotive business to visualize not only the difficulties of the engine builder but equally the problem of the oil producer.

Automotive engineers have come to realize that crude oil must be used to the best industrial advantage. Moreover, what is wasted today cannot be brought back. Mr. Crane urged particularly that the refiners make a careful study of the results of the Bureau tests, for which he himself had the highest admiration, rather than accept the interpretation placed upon them by any one man. He emphasized the importance of the carbureter-setting used by the average driver, which might be decidedly different from that used in the tests and therefore show up differ-

ences in the fuel. In concluding, he expressed an appreciation of the sincere desire on the part of the refiners to understand the difficulties of the problem facing the automotive industry and to cooperate in the solution of joint problems. He also urged greater uniformity in fuel on the basis of the results obtained in tests of Post-Office trucks run by the Bureau of Standards last summer, in which it was shown that any departure from the customary usage decreased the mileage.

T. G. Delbridge, of the Atlantic Refining Co. endorsed the sentiments of Mr. Chew. He called attention to the well-known unreliability of the judgment of the average user as to the quality of fuel. An important factor in the joint program was the preparation of the test fuels, and he explained the care given to this by the Atlantic Refining Co. The question as to what is good gasoline is not answered, but a vigorous prosecution of work along present lines will add much to our knowledge before the next annual meeting.

The afternoon session opened with a paper by O. C. Berry, of the Wheeler-Schebler Carbureter Co., who suggested finding the operating temperatures of the average automobile under different conditions in service, as a further guide in the work of the Bureau of Standards. Such measurement would show what part of the engine is at the controlling temperature as regards fuel vaporization, enable refiners to estimate the relative merits of fuels, and spur on the automotive engineer to greater efforts in the development of manifolds.

H. L. Horning, of the Waukesha Motor Co., said that the present fuel is all right as it is put out by the responsible refiners. The trouble is with the filling station and the garage men who mix in kerosene and other things and sell it for "gasoline." They are the men whom the refiners should watch. Mr. Horning stressed the importance of the Bureau of Standards tests. The equal mileages for all fuels was, he said, only a part of the story. Crankcase-oil dilution increasing with the end-point is shown even more conclusively by other tests, and it seems that dilution is the important factor.

The speaker then presented figures, obtained from the American Petroleum Institute, which showed that 69 per cent of the population and 83 per cent of the automotive equipment of the Country are located north of St. Louis. Above this latitude, temperatures below 50 deg. fahr. occur during about half the year, and below this temperature trouble occurs due to crankcase dilution. Mr. Horning then showed a curve giving the percentage of employes of the Waukesha company using their cars at different weather temperatures. Below 0 deg. relatively few cars were used.

The next speaker was R. Haskell, of the Texas Co., who called attention to the inappropriateness of the term end-point. Three main factors in successful engine operation are the fuel, the engine and the operator, and of the three the last is the most important.

Present Status of Problem

Dr. H. C. Dickinson, research manager of the Society, gave a brief review of the reasons for undertaking the joint research, and of the present status of the problem. Of the four factors that determine fuel utilization value, namely, mileage, starting ability, crankcase-dilution and carbonization, the tests have covered the first, for summer conditions; have not touched on the second or fourth; and have given some information on the third. There is much more to be done.

Dr. Frank A. Howard, of the Standard Oil Co. of New Jersey, pointed out briefly how many of the questions of 2 or 3 years ago, such as knock and mileage, have been answered at least partially, and raised the question whether crankcase-dilution is not of much less importance than it is generally supposed to be.

E. B. Phillips, of the Sinclair Refining Co., said that the refiners are "on their toes," trying to give the consumer the best gasoline they can make out of the material at hand. R. E. Wilson, of the Standard Oil Co. of Indiana, brought out the point that if carbureter-settings were made for maximum economy instead of for maximum power, differences between the test fuels would be expected, but as the average driver sets for maximum power, the reported test-results are typical.

He then discussed at some length the relation of the conventional distillation-curve to the true volatility of the gasoline and stated that the effective upper distillation-temperature is nearly proportional to the temperature of the 85-per cent point. He made a strong plea for a more rational type of volatility specification, giving only the 20 and 85-per cent points instead of a number of points as at present. This material was published in THE JOURNAL.[2]

Natural Gasoline

W. M. Welch, of the Association of Natural Gasoline Manufacturers, presented an interesting paper on the relation of natural gasoline to the fuel problem. Natural gasoline was an "outlaw" product 2 or 3 years ago. Its value is now recognized and methods of blending have been perfected so that it has come to be a most important factor in maintaining a satisfactory volatility. The amount now used is probably 10 per cent of the total gasoline marketed. The speaker suggested that the joint research be extended to include the starting characteristics of fuels blended with natural gasoline.

The Friday session of the meeting was devoted to a discussion of the heavy-fuel engine, with special emphasis on its application to motor transportation.

New Engine Types

First on the program was a paper by H. L. Doherty, which was presented by T. R. Coates, of the Toledo Edison Co. The author maintained that the petroleum industry demands the development of two types of engine in addition to those in use at present. These are

(1) A small heavy-duty engine of simple and inexpensive construction, that will serve for truck, tractor and for small stationary use. Maximum fuel-economy is not essential

(2) An engine of much larger size and of much lower initial-cost than present Diesel practice demands, for boat propulsion and for use as a stationary engine

Some of the fundamental difficulties with the combustion turbine were pointed out, and it was recommended that all proposals along this line receive careful analysis by high-class physicists before they are given financial support.

The second paper was by Harte Cooke of McIntosh & Seymour Co., who recounted some of the difficulties encountered in the course of many years' experience with injection engines designed chiefly for stationary service; difficulties mainly of a mechanical nature, such as clogging of the injection valves. The lighter oils are not satisfactory because of vaporization in the injection system, where heat is applied. Regulation of the temperature of the fuel is important to control the viscosity at the injection valve.

A point of some interest to the automotive engineer was

[2] See THE JOURNAL, January, 1922, p. 6.

brought out in a statement regarding sulphur in the fuel. It was said that sulphur up to 3½ per cent has no deleterious effect on the engine, provided a change is made to a sulphur-free fuel just before stopping; otherwise serious rusting of the cylinder walls and manifold will result after the engine has stood even for as short a time as a few hours.

F. W. Gay, of the De La Vergne Co., in the next paper also referred to sulphur in fuels as giving trouble, but stated that there is very little trouble with lubrication; less than with steam engines. Fuels with 6 or 8 per cent of sulphur had been used.

W. G. Gernandt discussed the development of a small fuel-injection engine for which he claims a speed range of from 250 to 2250 r.p.m. for a single-cylinder model, and of from 200 to 2500 r.p.m. for a four-cylinder engine of 2⅜-in. bore and 5-in. stroke.

Prof. C. E. Lucke, of the Worthington Pump & Machinery Corporation, compared the situations as regards the two distinct engine-types that have to be considered in connection with fuel utilization. The one group, represented by the automobile engine, requires fuel that is specially prepared for its use and cannot go far beyond the present range in fuel quality. This type has the weight of a great industry back of it, and can demand what it requires, but cannot readily change. The other group is represented by the heavy-oil engine in its various forms. It can use almost any kind of fuel, but has not powerful backing to facilitate its ready development. Professor Lucke went on to discuss the basic differences between the two types and pointed out that the injection type of engine is not limited as to fuel quality or as to compression pressure, both of which make high economy possible. The reasons for slower development of this type are greater engineering difficulties in design and a patent situation that has limited progress almost to the present time.

Professor Lucke discussed at some length the real progress that has been made, and concluded that the most serious problems, those of injection at high speed, proper spraying and cylinder form, have been solved. Reduction of weight and of cost are to be accomplished still, but there are precedents which show that both are possible.

Finally, the author proposed a program of concerted research to solve some of the outstanding problems of the injection engine, such as the physics of the various fuels and their behavior in small passages at high pressures and the physics of air at high pressures and temperatures, and called upon the oil industry to further these lines of development and promote as far as possible the use of the heavy-oil engine.

Max Rotter, of the Busch-Sulzer Brothers Co., presented his paper by title, but discussed Professor Lucke's paper briefly. He said that the producers of lubricants have cooperated in Diesel development because the sale of lubricants was thereby increased, but that the fuel-oil producers have not been interested because the demand for fuel oil is decreased by Diesel development. The paper itself discussed the field of application of the Diesel engine as compared with steam, and showed that its most advantageous use is for moderate-size stationary and marine plants. In very large sizes the advantages over the steam turbine are not so marked. Diesel engines can now use almost any liquid fuel, but the fuel producers have done little to standardize or to improve the situation. The makers of lubricants, on the other hand, have improved their product considerably.

A paper by Arthur West, of the Bethlehem Steel Corporation, also read by title, was followed by several brief discussions. The trend of the fuel prices and the inevitable demand for higher thermal efficiencies were topics. The author stated that the efficiencies of steam units are more limited than those of the injection-type heavy-oil engine. He was of the opinion that the costs of Diesel-engine installation are likely to decrease due to the increased quantity production and the increase in the size of the units; also that the obsolescence period of the Diesel engine should be rated as longer than that of a turbine plant.

WORLD OIL-PROBLEMS

THE aggregate acreage of all the actually producing areas in the United States is insignificant compared with the total area of the sedimentary rocks in this country. There are numerous examples in the past history of the oil industry of tests having been drilled in a region without success, the region abandoned and then, after a time, redrilled and found to contain important oil deposits. It is only reasonable to suppose that there will be additional examples of this in the future. It is a fact that the greater part of the United States has not yet been conclusively tested for oil. The mathematical chance of large untapped oil reserves in the United States is of a different character, in a positive direction, than the careful estimates already made would lead one to believe.

For a great nation to say, "Since oil is a prime necessity to us in case of war, the oil resources of our State must be developed by our own nationals," overlooks the economic and practical points that very large sums are required to develop new oil regions, and that much of the money spent in prospecting is not productive, that in case of war only developed oil fields have practical value and that, should there be a war, any developed oil field would be immediately mobilized, irrespective of whether the development was due to domestic or foreign capital. It is better economics to have the losses of development shared by foreign capital than to have the whole loss fall at home. The most complete self-interest and self-advancement says "Throw the doors wide-open."

The oil resources of the world as a whole are large beyond any calculation possible at the present time. It is now demonstrated that commercial petroleum may occur in sedimentary rocks of any age from the oldest to the youngest and in any structural position. The sedimentary rocks occupy the greater part of the earth's surface. Those found in the United States are but a small part. It is only in the United States that these sedimentary rocks have been extensively developed for oil. As the ultimate production of the United States is to the area of the sedimentary rocks of the United States, so the ultimate total oil production of the world will be to the whole area of sedimentary rocks of the world.

But, vast as the oil resources of the world are, they must be developed, if the constantly increasing needs of civilization are to be met. The United States has borne the great portion of the burden of the world's oil requirements, giving freely from its natural resources for the benefit of commerce and civilization. Unless foreign oil-fields are developed more thoroughly, the time must inevitably come when all nations will be seriously handicapped.

There are many regions in Europe, which contain promising oil territory, whose development is prevented by antiquated laws, international jealousies and local national feeling, all to the detriment of the countries concerned. The more rapidly the lessons of past mistakes are realized and corrected, the more rapidly real progress will be made. One point grows increasingly clear, far from facing world oil-exhaustion, the oil industry is at the present time merely on the threshold of a glorious future.—A. C. Veatch at American Petroleum Institute meeting.

FEDERAL ROAD MONEY

THE post-office appropriation authorizes expenditures of $190,000,000 in Federal aid for road construction. Fifty million dollars is authorized for the fiscal year beginning July 1 and $65,000,000 and $75,000,000 respectively for each of the two succeeding fiscal years. In addition, $13,000,000 is authorized for forest roads for the two fiscal years 1923 and 1924. The funds will be administered by the Secretary of Agriculture through the Bureau of Public Roads. These funds must be matched by the States and will be administered subject to the general provisions already in force.

The new legislation reduces the maximum participation on the part of the Federal Government from $20,000 to $16,250 per mile for roads constructed with the appropriation during the next fiscal year and to $15,000 a mile thereafter. Bridges over 20 ft. in span may be considered as separate projects to which this limitation does not apply. The new appropriation comes at a time when several States are nearing the limit of funds available. The authorization of funds for 3 years in advance will be of great benefit to all States in that it will permit them to lay their plans for some time ahead.

Heretofore $350,000,000 has been appropriated. On May 31 17,000 miles of road had been completed and in addition nearly 14,500 miles were under construction. Federal-aid roads in all stages total nearly 38,700 miles, costing over $287,500,000 in Federal aid. The States have appropriated approximately $380,000,000, making a total of $667,500,000. All types of road have been constructed with Federal aid to meet the varying conditions in the United States. The average cost per mile has been $17,120; Federal aid has amounted to 43 per cent of the total cost.

It is estimated that the $190,000,000 lately authorized will result in the construction of more than 25,000 miles of improved roads, which, added to the 46,000 miles that is expected to result from previous appropriations, makes a total of 71,000 miles, or nearly 40 per cent of the estimated 180,000 miles of road in the system of Federal-aid roads now being outlined.

FATIGUE OF METALS

IN a lecture delivered to the Royal Institution in 1914, the late Lord Rayleigh quoted some exasperated experimentalist to the effect that the classical theory of hydrodynamics as developed by Euler and Lagrange had no connection with the actual behavior of real fluids. The practical engineer could find, in the records of experience, grounds for an equally unrestrained indictment of the mathematical theory of elasticity. In each case the criticism, though not wholly without foundation, is too sweeping in character, and both mathematical theories have proved of very considerable service to the practician, in spite of the fact that the ideal materials, to which alone they apply without restriction, remain mere figments of the imagination.

It was inevitable that the successful development of stress analysis during the nineteenth century should have led those versed in it to underestimate the importance of the empirical factor involved in the fixation of working stresses. Fairbairn seems to have been the first to state definitely that the permissible working-stress on an iron structure is not a fixed quantity, but varies with the character of the loading. This conclusion was at the outset based on observation and experience. Although some explanation of Fairbairn's and Wohler's results had been supplied in anticipation by James Thomson's demonstration of the fact that the raising of the tension elastic-limit of a material by stretching it, involves a lowering of the compression limit, the reality of fatigue continued to be disputed even after Thomson's conclusions had been confirmed by the elaborate experiments of Bauschinger. Bridge engineers in particular were prone to attribute to the effects of impact the necessity of adopting lower unit-stresses in proportioning structures intended to carry relatively high loads.

Whatever views may be held as to the mechanism of failure by fatigue, all agree that the safe permissible stress is a function of the number of times it is repeated. The National Research Council estimates that a steam turbine may make 15,000,000,000 revolutions during its working life and a steam engine 1,000,000,000. This latter figure probably refers to land practice and to high-speed engines and can hardly be attained in sea service. Car axles are attributed a life of 360,000,000 revolutions; while main bridge-members are only called upon to undergo 2,000,000 repetitions of stress. It is of interest to note that according to this estimate rails are subjected in their lifetime to half a million repetitions of engine wheel-loads, but to 15,000,000 repetitions of the car wheel-loads.

When the phenomena of fatigue first began to be generally recognized the belief was common that the long-continued vibration caused the material to crystallize, and the older textbooks made frequent references to the fibrous character of surfaces that had failed under a steady stress. Now, however, it is known that, even in typically fibrous materials, the ultimate constitution is really crystalline, and the characteristic appearance of fatigue fractures is attributed to the progressive character of the failure.

As the result of investigations carried out at the University of Illinois by Prof. H. F. Moore and Prof. J. B. Kommers, on behalf of the National Research Council and others, some interesting conclusions have been reached. In all cases it was indicated that the endurance limit of a material can be obtained with experiments not extending beyond 10,000,000 repetitions of stress. The observers relied for the most part on rotating-bar tests, which have the advantage that very high rates of alternation of stress can be employed without risk of errors from inertia effects. The specimens were subjected to a bending-moment that was uniform over a length of about 3 in. It was found necessary to have this portion of the beam of much smaller diameter than the remainder, since without this precaution fracture always occurred at the collets, where the loads that produced the uniform bending-moment were applied. Moreover, in making the change of section, fillets of very large radius were found essential. Thus the main body of the bar being 0.4 in. in diameter and the reduced section 0.3 in., a radius of 0.5 in. at the junction was proved to be too small. Ultimately this reduced section was made as one continuous curve of 9.85-in. radius from end to end, which gave a practically parallel section about 0.20 in. long at the middle point.

A notable point brought out in these experiments is that the surface finish has an important bearing on the capacity to withstand alternating stresses. Rough-turned specimens show 20 per cent less endurance than polished ones. Test-pieces finished by grinding, though better than if merely machined, were still distinctly inferior to those with polished surfaces. There was, however, no material difference between specimens finished with rouge and those polished with emery cloth in the usual way.

One interesting result was that the ultimate-strength of the material was a somewhat more reliable index of its endurance than was the elastic-limit. The Brinell test was, however, still better; while the notched-bar tests were unsatisfactory in this regard. Of course, in this connection it must be borne in mind that, in practice, tests are made with different objects. For the most part the suitability of a material for a given purpose is estimated from the results of practical experience with it, and the purchaser accordingly merely requires some simple and rapid test to ensure that he is being supplied with the material specified, and that this is of uniform quality. Undoubtedly the notched-bar test provides a very drastic test of this latter quality.

But even 10,000,000 repetitions of the stress require several days to complete, and a less tedious plan would be highly advantageous. This appears to be afforded by Stromeyer's method, which is based upon the fact pointed out by Lord Kelvin in 1855 that a specimen is cooled by stretching it within its elastic-limit and heated by compressing it. On the other hand, any permanent distortion always heats the bar. Hence, if subjected to an alternating stress, so long as the internal work done is wholly elastic the rise of temperature produced by compression will be annulled by the reduction of temperature due to tension, and the mean temperature will remain unchanged. So soon, however, as permanent changes are produced within the metal there will be a rise of temperature.

It has been asserted that once a material has been strained beyond its elastic-limit it is ruined, a contention that is maintained in spite of the fact that plates for boiler shells are bent to form cold, and appear none the weaker for this treatment. In this connection some of the experiments made at the University of Illinois are of special interest. Suppose the endurance limit of a material, under alternating stress, has been determined, that is to say, the stress of which it will endure an unlimited number of repetitions. What will be the effect of submitting it at the outset to a limited number of higher stresses? The Illinois observers conclude that a 38-per cent over-stress applied 100 times does not permanently injure the material, but a 35-per cent over-stress applied 1000 times did apparently reduce the endurance by 4 per cent. This fact is obviously one of great interest, as it indicates that an occasional temporary overload of a machine part is of no practical importance. This conclusion may possibly lead to a revision of current ideas as to the importance of temperature stresses. It is, moreover, noteworthy that high-carbon steels were found to suffer more from occasional overloads than the softer structural materials.—*Engineering* (London).

Current Standardization Work

AS indicated in several articles appearing in the December issue of THE JOURNAL, the Standards Committee has been most active during the last few months. The status of over 50 of the 100 live subjects before the Standards Committee Divisions changed during November, which is exceptional in view of the fact that over 75 per cent of the subjects have been awaiting Subdivision action.

BRAKE-LINING

The Technical Committee of the Brake-Liners Association has recommended that the following list of inch sizes of brake-lining be accepted as an S.A.E. Standard.

1¼ x 5/32	1½ x 1/8	2 x ¼	3 x 5/16
1½ x 5/32	1¾ x 1/8	2½ x ¼	3½ x 5/16
1¾ x 5/32	2 x 1/8	3 x ¼	4 x 5/16
2 x 5/32	2½ x 1/8	4 x ¼	

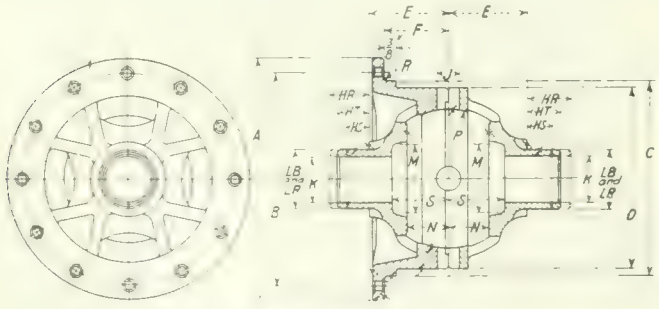
It is thought that the adoption of such a revision would place the brake-lining manufacturers in a better position to object to making odd sizes such as 1⅞ x 5/32 in. The suggestion has been referred to the Brake-Lining Subdivision of the Parts and Fittings Division, which has been working on the standardization of brake-lining tests and specifications for some time in cooperation with the Bureau of Standards and manufacturers. Brake-lining testing-machines have been developed and are being used by several of the manufacturers, the tests that have been made having been carefully checked at Subdivision meetings. At the last meeting, however, the results indicated that further development work would have to be undertaken before the testing machines would meet the requirements of the industry.

CAST-IRON SPECIFICATIONS

At the last meeting of the Iron and Steel Division it was decided that the present S.A.E. Standard for iron and steel specifications should be extended to include the statement that the Division deems it inadvisable to formulate specifications for cast iron by chemical requirements, in view of the wide range of conditions to be met.

CLUTCH-RELEASE-TYPE THRUST BALL-BEARINGS

The present S.A.E. Recommended Practice for Clutch-Release-Type Thrust Ball-Bearings was adopted by the Society in July, 1921, and is printed on p. B39 of the S.A.E. HANDBOOK. Several objections to it have been raised by Society members. At the meeting of the Ball and Roller Bearings Division on Nov. 9 this subject was discussed informally. It is believed that the criticisms submitted are amply justified. The Standards Department was requested to circularize the users of this type of bearing to ascertain definitely the extent of the use of the recommended practice.



LB and *HT* for taper roller bearings
LB and *HS* for ball bearings
LR and *HR* for straight roller bearings

DIFFERENTIAL GEARS

The Subdivision on Differential Gears of the Axle and Wheels Division has been working in cooperation with a similar committee of the American Gear Manufacturers' Association with a view to formulating a standard for passenger-car and motor-truck differential gears and cases. A tentative recommendation has been adopted and is shown in Figs. 1 to 5.

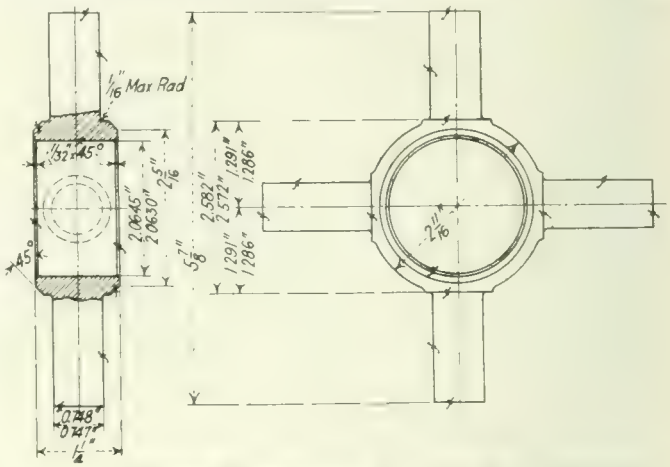


FIG. 2—PROPOSED RECOMMENDED PRACTICE FOR 11-20 RATIO GEARS

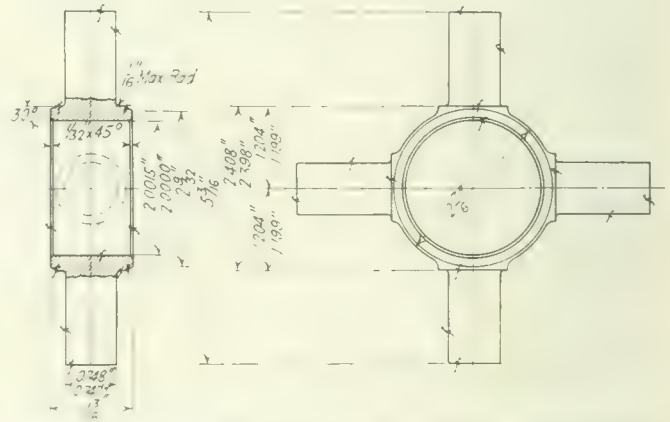


FIG. 3—PROPOSED RECOMMENDED PRACTICE FOR 10-18 RATIO GEARS

It is felt that the present large variety of designs can be greatly reduced through the adoption of the proposed standards in practice, thereby decreasing manufacturing costs, conserving material, lessening dealers' and service-stations' necessary stock of spare-parts and greatly facilitating replacement of worn or broken parts in passenger cars and motor trucks.

FIG. 1—PROPOSED RECOMMENDED PRACTICE FOR TWO-PIECE DIFFERENTIAL CASE

Differential No.	A	B ± 0.003	C — 0.002	D	E	F max.	HT	HS	HR	J ±0.001	K	LB	LR	M	N ±0.001	P ±0.001	R	S	Drill No.	Holes Diam.
11-20	8 1/8	7.125	6.500	6	2 3/8	2 1/8	7/8	31/32	1 1/16	0.750	1 5/16	2.1669 2.1660	2.1654 2.1645	2 1/16	1.377	2.315	1/16	1 7/8	12	21/64
10-18	7 3/8	6.625	6.000	5 1/2	2 3/8	2 1/8	7/8	31/32	1 1/4	0.750	1 5/16	1.9699 1.9691	1.9685 1.9677	2 1/16	1.283	2.079	1/16	1 13/16	10	21/64

Although the proposal includes many detailed dimensions, the Division has not definitely decided as to what extent detailed dimensions should be specified. Standard outside dimensions of the case would permit of interchanging or replacing cases, whereas complete standardization as tentatively proposed would tend to reduce the cost of making gears and permit individual car-owners to interchange or replace parts within the case. The recommendation proposed has been submitted to the industries generally for criticism, particularly regarding the extent to which detailed dimensions should be included. It will also be submitted as a progress report at the Standards Committee Meeting on Jan. 9 if time permits.

The standard is not intended to meet the requirements of present designs, but as a guide for future designs. It cannot be expected to meet all requirements, but should be of material value to users and makers of differentials.

Engine Numbers

At the last meeting of the Engine Division, R. S. Begg, chairman of the Passenger-Car Division, submitted a number of additional samples embodying methods for numbering engines and frames. Photographs and samples of the various methods that have been tested by the Underwriters' Laboratories, all of which were considered to have failed to meet the necessary requirements, were also submitted. It was stated that only one method of changing the numbers on each sample had been tried, but that there are probably other methods equally or possibly more effective which further study would have brought out. Upon completion of all tests by the Underwriters' Laboratories, a complete report illustrated with photographs of all samples submitted by the Society and received from other sources will be available.

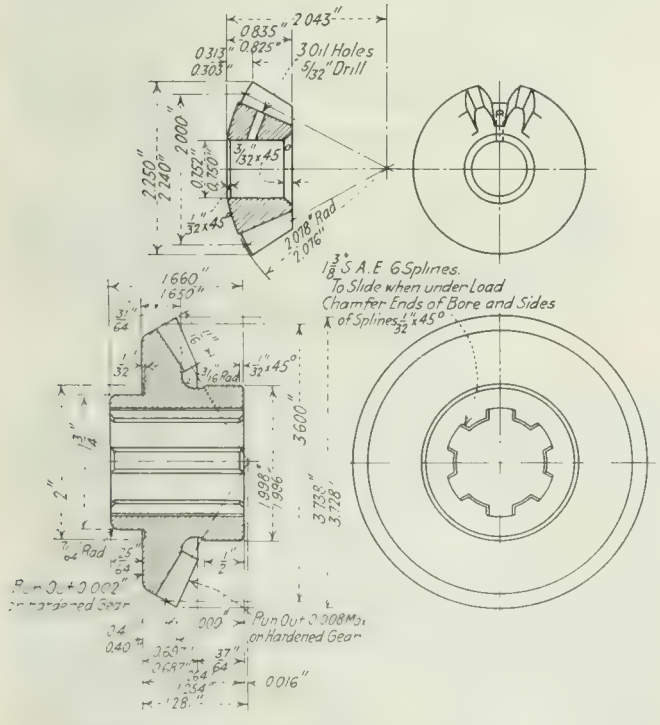


FIG. 4—PROPOSED RECOMMENDED PRACTICE FOR 10-18 DIFFERENTIAL GEAR AND PINION

	Gear	Pinion
Number of Teeth,	18	10
Diametral Pitch	5-7	5-7
Pitch Angle, deg.-min.	60-57	29-3
Face Angle, deg.-min.	64-55	33-1
Chordal Thickness, in.	0.3093	0.3153
Corrected Pitch Depth, in.	0.1453	0.1505
Addendum, in.	0.1429	0.1429
Dedendum, in.	0.1785	0.1785
Block Angle, deg.-min.	4-57	4-57
Pressure Angle, deg.	20	20

The chordal thickness allows for 0.006-in. backlash.

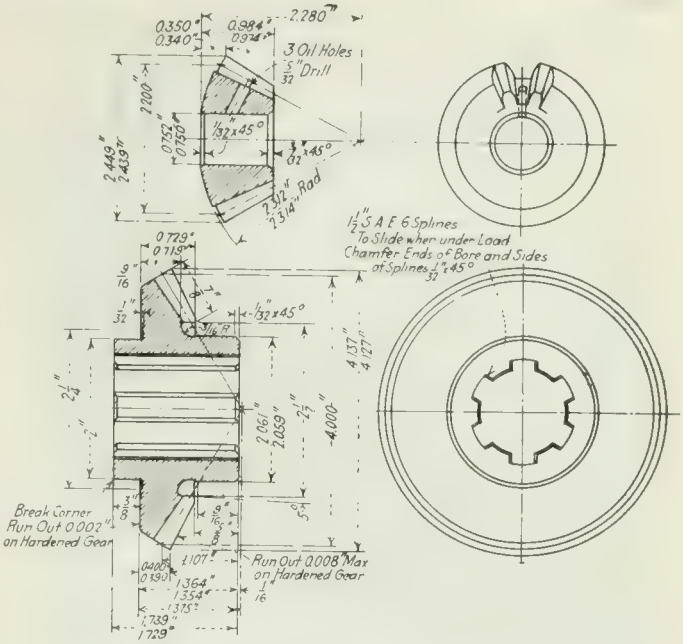


FIG. 5—PROPOSED RECOMMENDED PRACTICE FOR 11-20 DIFFERENTIAL GEAR AND PINION

	Gear	Pinion
Number of Teeth,	20	11
Diametral Pitch	5-7	5-7
Pitch Angle, deg.-min.	61-11	28-49
Face Angle, deg.-min.	64-46	32-24
Chordal Thickness, in.	0.3080	0.3130
Corrected Pitch Depth, in.	0.1459	0.1530
Addendum, in.	0.1429	0.1429
Dedendum, in.	0.1785	0.1785
Block Angle, deg.-min.	4-22	4-22
Pressure Angle, deg.	20	20

The chordal thickness allows for 0.006-in. backlash.

Flexible Discs

The Parts and Fittings Division has undertaken the standardization of bolt-circle diameters, inside diameters, outside diameters and thicknesses of flexible discs used for propeller-shaft couplings. C. W. Spicer and E. W. Templin have been appointed a Subdivision to obtain information and prepare a report to the Division.

Flywheel Housings

An inquiry as to whether 8 or 12 holes should be specified for the S.A.E. Standard No. 5 flywheel housing flange was discussed at the last meeting of the Engine Division. As very few of the engine builders make engines requiring this size of housing, it was decided that the Standards Department should make inquiry as to what companies are using it and what mounting dimensions are considered good practice.

Iron and Steel Specifications

At the last meeting of the Iron and Steel Division it was pointed out that the present S.A.E. steel numbers are not always used by purchasers of S.A.E. standard analyses, private specification numbers being substituted. It was thought that there is absolutely no good reason for this and that the American Iron and Steel Institute should be requested to take steps to counteract the practice if possible.

The suggestion that the minimum sulphur-content for screw-stock specifications No. 1112 and 1120 be changed from 0.075 to 0.090 per cent, the other elements remaining the same, was discussed. It was decided that the the Standards Department should circularize representative steel and pas-

senger-car producers, as well as cold-drawn bar and shafting manufacturers, in reference to the advisability of this.

The matter of the standardization of molybdenum steels was reopened on the basis of several communications received from Society members. Chairman Gilligan outlined the previous action of the Council in not assigning the subject of molybdenum steels to the Division, due to the rule of the Standards Committee that prohibits the standardization of patented articles. It was stated that several of the steel companies receive a large number of inquiries for various molybdenum-steel compositions and that the standardization of definite compositions would be of considerable help to the steel producers. As it was the consensus of opinion that the subjects of high-chromium and molybdenum steels should be assigned to the Iron and Steel Division on the basis that, if the composition of a steel is not similar to the composition of other steels and may be manufactured by any manufacturer taking out a license, there can be no objection against the standardization of it. It was also thought desirable to ascertain the extent of the use of all steel compositions and the Standards Department was authorized to send out a general questionnaire to the automotive and parts makers requesting data as to the tonnage of the various steels used.

The Division did not feel that the time was appropriate to consider submitting either the carbon or alloy-steel specifications to the American Engineering Standards Committee for consideration and adoption as a national standard. It was thought, however, that the Society is the proper body to sponsor such action when it shall be considered in order.

Fuel and Lubrication Pipe-Fittings

At the last meeting of the Parts and Fittings Division the present S.A.E. Standards for Fuel and Lubrication Pipe-Fittings, pp. C46 and C47 of the S.A.E. Handbook, were discussed. The tolerance on the diameter of the hole in the extended portion for the flared-tube type that holds the tubing so as to prevent vibration, was considered with reference to possible revision. It was felt, however, that before any changes in the standard were undertaken, a careful analysis of present practice should be made, as present production of standard fittings constitutes over 50 per cent of the total production.

The Division has been working for some time also on the standardization of compression-type fittings. It is felt that any standard adopted should be based on current production.

Lubrication of Springs

Replies received to inquiries sent out recently as to the possibility of standardizing spring lubricants indicated a considerable difference of opinion as to the necessity of lubricating springs and the type of lubricant that should be used. The Springs Division has therefore decided to discontinue this subject.

Footman Loops

At the last meeting of the Passenger-Car Body Division it was suggested that a standard for footman loops would, if adopted in practice, overcome the necessity of making a large variety of designs and sizes. A type of loop which was thought satisfactory for all general applications was submitted and the Standards Department asked to circularize it for approval as a tentative recommendation of the Division. This type is shown in Fig. 6. Standard footman loops would be of value also to strap manufacturers.

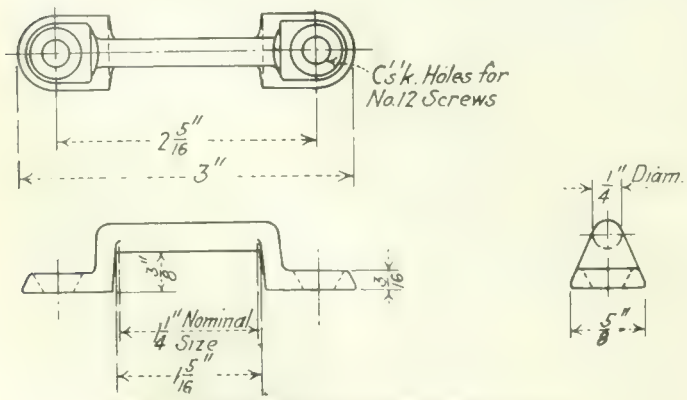


Fig. 6 - Proposed Standard for Footman Loops

License-Plates and Brackets

At the last meeting of the Parts and Fittings Division, W. C. Keys submitted a report based on data received from several States indicating the largest sizes of passenger-car, motor-truck and motorcycle license-plate used. The plate dimensions proposed were based on sizes used in California, Illinois, Indiana, Michigan, New York, Ohio and Pennsylvania, in which States the majority of automobiles are registered. The report was approved in a revised form, the minimum as well as the maximum plate-lengths being specified and the holes in the plates located so that all plates for a given type of vehicle could be mounted on one size of bracket. The proposal as approved is given in Fig. 7 and is to be circulated by the Standards Department among the several States for further comment or approval before final Division action shall be taken.

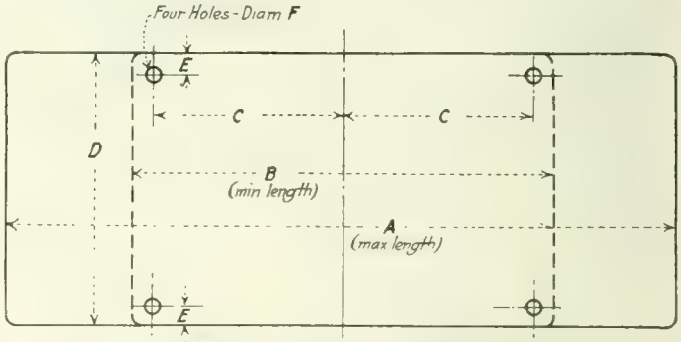


Fig. 7. Proposed Standard for License Plates

Type of Plate	A	B	C	D	E	F
Automobile[1]	16	10	4¼	6½	½	9/32
Motorcycle	8¾	5	2	4½	⅜	7/32

[1] Includes both passenger cars and motor trucks.

Motor-Truck Rating

A meeting of the Motor-Truck Rating Subdivision of the Truck Division was held on Nov. 20, 1922. A. K. Brumbaugh, chairman of the Subdivision, D. C. Fenner, A. J. Scaife, A. L. McMurtry and F. W. Fenn were present. Mr. McMurtry, formerly connected with the Motor Vehicle Commissioner's Office of the State of Connecticut, stated that public feeling against motor trucks is increasing rapidly because of careless and unsafe methods of operation, and that this will lead to more drastic action by State legislatures. It was his opinion that the problem of rating, based on regulations for brakes, steering-gears and axles is largely one of adequate maintenance in operation, particularly as these parts are well designed on recognized makes of motor truck. He felt that the most effective way to accomplish the desired results is to require the placing of a permanent plate on every motor-truck chassis giving the following information:

The gross permissible load on the front axle
The gross permissible load on the rear axle
The maximum speed
The maximum allowable stopping-distance in feet, from the maximum speed under normal conditions with the motor truck fully loaded, and applying either set of brakes independently of the other

Such plates would have to be filled out for every motor truck licensed. No trouble would be expected from new trucks made by recognized builders and with such plates attached to them they could be checked readily by inspectors on the road. This suggestion would, in Mr. McMurtry's opinion, answer practically all requirements for regulations,

leaving to the builders the determination of their motor-truck ratings, they furnishing their trucks with the plates properly stamped rather than being required to conform to an arbitrary rating. The owners of "orphan" trucks would then have to apply to the State officials for their plates and before these would be issued the truck would have to be examined by State inspectors.

After general discussion, it was decided to discontinue further consideration of the Subdivision's previous proposition for the regulation of brakes, steering-gears and axles, and to recommend tentatively that all motor trucks be equipped with plates giving the requirements necessary for safe operating conditions, and that this recommendation be circulated by the National Automobile Chamber of Commerce among its members and other truck companies in order that prompt and wide publicity might inform the public and legislators that attention is being given to providing an adequate remedy for present conditions without working a hardship on the manufacturers. The Subdivision of the Society's Standards Committee is working in cooperation with the Motor-Truck Committee of the National Automobile Chamber of Commerce. The subject of motor-truck rating is being handled by the Society as a special subject and action on it will therefore be reported direct to its Council.

Nickel-Plating

It was stated at the last meeting of the Passenger-Car Body Division that there are major problems to solve in connection with nickel-plating on steel and enameling on brass. Considerable trouble with the plating on steel peeling, especially on oversea shipments and cars or parts held in storage, has been experienced and no satisfactory way of overcoming the condition has been found. It was the consensus of opinion that nickel-plating on iron and steel, even when they are first plated with copper or zinc, should not be used except where structural conditions make it necessary to do so. The subject will be considered further.

Paints, Varnishes and Enamels

This subject was discussed at the last meeting of the Passenger-Car Body Division and considered important. It was felt that any work the Division could do would be of material assistance in bringing the makers and the users of the products to a closer understanding regarding their mutual requirements and limitations. A Subdivision is to be appointed to investigate the subject thoroughly.

Poppet Valves

The Subdivision on Poppet Valves held a meeting recently but no agreement was reached as to the extent or character of a desirable poppet-valve standard. Tentative specifications are to be considered by the various members of the Division and discussed at a subsequent meeting.

Radiator Nomenclature

Herbert Chase, writing in the Nov. 16, 1922, issue of *Automotive Industries*, has suggested definitions for various types of radiator core. These have been referred to the Radiator Division in connection with desirable revision of the present automobile nomenclature for radiator parts now printed on p. K5 of the S.A.E. Handbook. The definitions suggested by Mr. Chase follow.

Fin-and-Tube Type.—The fin-and-tube type radiator core is one made from continuous water-tubes over which the fins are fitted. The tubes have various shapes of transverse section, but are not crimped and are not of that wide, flat type which is formed by joining two metal ribbons at each edge

Ribbon Cellular Type.—The ribbon cellular type of radiator core is one made from continuous water-tubes formed by joining two metal ribbons at each edge. The walls of the tubes are usually crimped and grouped so as to form a cellular structure. In some cases a part of the cellular structure is formed by flat or crimped ribbon, which is not a part of the water-tube walls

Air-Tube Cellular Type.—The air-tube cellular type of radiator core is one made from air tubes that are nested in such a way as to form water-passages between the tubes, these passages being sealed by soldering at the ends of the tubes. In this type of core the general direction of water flow is at right angles to the tubes, but the water can flow transversely as well as vertically through the passages between the tubes

Rod-End Pins

When the present S.A.E. Standard for Rod-End Pins, p. C8 of the S.A.E. Handbook, was adopted, it was general practice to mill the heads on the pins. Due to developments in production, it is now the general practice to form these heads by upsetting. As the tolerances on upset pins are necessarily larger than those on milled pins, it is considered important to revise the present tolerances on the diameters of the holes in the rod-ends. At the last meeting of the Parts and Fittings Division, W. J. Outcalt was appointed a Subdivision to prepare a report on upset rod-end pins to fit the present rod-end holes.

Rolled-Sections

The standardization of steel and aluminum rolled-sections is one of the most important subjects before the Passenger-Car Body Division. Although a tremendous number of sections are used, it is felt that all requirements can be met by a few standard sections. Only the simpler sections, such as ovals, quarter-ovals, tees, rain-drips and gutters will be taken up at first, as the more complicated sections are more difficult to standardize. It is argued that there is need to establish standard hardness specifications for aluminum moldings because at present they vary widely in their degree of hardness.

Sheet Aluminum

At the meeting of the Passenger-Car Body Division held in November it was indicated that the present S.A.E. Standard for Sheet Aluminum, p. D121 of the S.A.E. Handbook, does not entirely answer body-makers' requirements, as it does not limit the number of sheet sizes. It was felt that a supplementary standard for sheet aluminum listing a limited number of gage thicknesses, specific sheet sizes and definite tempers, should be adopted. R. A. La Barre was appointed a Subdivision to draft a report in this connection.

Taper Fittings

The Motorboat Division expressed the view that the present standards for motorboat couplings should be revised in accordance with the standard on taper fittings for plain or slotted nuts, p. C14 of the S.A.E. Handbook. The present motorboat coupling standards specify "non-standard" nuts in many cases. It was found, however, that the present standard for taper fittings does not include fittings for the 1⅝, 1⅞ and 3¼-in. shaft sizes that are used extensively in motorboat practice. The Motorboat Division asked that the Parts and Fittings Division extend this standard accordingly. The request was referred to C. W. Spicer, of the Spicer Mfg. Corporation, who was largely responsible for the formulation of the original standard, and a report was recently submitted and approved by the members of the Division.

Metric-Type Roller Bearings

At the October, 1921, meeting of the Ball and Roller Bearings Division it was felt that there was sufficient demand for standard metric-type roller bearings that are interchangeable with wide or double-row type ball bearings to warrant the Society in continuing to publish the present roller-bearing standards on pp. C43 and C44 of the S.A.E. Handbook. As the discussion indicated that the present dimensions of the standard metric-type roller bearings are in general satisfactory it was decided to request the Roller Bearing Subdivision to continue consideration of the revisions of the present standards as to tolerances, widths and corner radii as proposed at a Subdivision meeting on Nov. 20, 1918.

TABLE 1—LIGHT-SERIES METRIC ROLLER-BEARING DIMENSIONS

Bearing No.	Inside Diameter			Outside Diameter			Width, In. Plus or Minus 0.020	Radius or Chamfer[2] C				Eccentricity Tolerances of Races, In.		Cage Clearances, In.[3]	
								Max.		Min.					
	Mm.	In.	Tolerances in Inches Plus 0.0002 Minus	Mm.	In.	Tolerances in Inches Plus 0.0000 Minus		Mm.	In.	Mm.	In.	Inner	Outer	Diam.	Width
L 04	20	0.78740	0.0004	47	1.85040	0.0006	3/4	1.5	0.06	1	0.04	0.0006	0.0012	1 11/32	0.16
L 05	25	0.98425	0.0006	52	2.04725	0.0008	3/4	1.5	0.06	1	0.04	0.0008	0.0012	1 13/32	0.16
L 06	30	1.18110	0.0006	62	2.44095	0.0008	3/4	4.0	0.16	2	0.08	0.0008	0.0012	2 3/16	0.16
L 07	35	1.37795	0.0006	72	2.83465	0.0008	7/8	4.0	0.16	2	0.08	0.0008	0.0012	2 5/16	0.16
L 08	40	1.57481	0.0006	80	3.14962	0.0008	1	4.0	0.16	2	0.08	0.0008	0.0012	2 13/32	0.16
L 09	45	1.77166	0.0006	85	3.34647	0.0008	1	4.0	0.16	2	0.08	0.0010	0.0016	3 1/32	0.20
L 10	50	1.96851	0.0006	90	3.54332	0.0008	1	4.0	0.16	2	0.08	0.0010	0.0016	3 3/16	0.20
L 11	55	2.16536	0.0006	100	3.93702	0.0008	1 1/16	5.0	0.20	3	0.12	0.0010	0.0016	3 5/8	0.20
L 12	60	2.36221	0.0006	110	4.33072	0.0008	1 1/8	5.0	0.20	3	0.12	0.0010	0.0016	3 13/32	0.20
L 13	65	2.55906	0.0006	120	4.72443	0.0008	1 1/8	5.0	0.20	3	0.12	0.0010	0.0016	4 5/16	0.20
L 14	70	2.75591	0.0006	125	4.92128	0.0008	1 1/16	5.0	0.20	3	0.12	0.0010	0.0016	4 1/2	0.24
L 15	75	2.95277	0.0006	130	5.11813	0.0008	1 1/16	5.0	0.20	3	0.12	0.0010	0.0016	4 11/16	0.24
L 16	80	3.14962	0.0006	140	5.51183	0.0008	1 1/4	5.0	0.20	3	0.12	0.0012	0.0018	5 1/16	0.24
L 17	85	3.34647	0.0007	150	5.90554	0.0012	1 3/4	5.0	0.20	3	0.12	0.0012	0.0018	5 3/8	0.24
L 18	90	3.54332	0.0007	160	6.29924	0.0012	2	5.0	0.20	3	0.12	0.0012	0.0018	5 5/8	0.28
L 19	95	3.74107	0.0007	170	6.69294	0.0012	2 3/16	5.0	0.20	3	0.12	0.0012	0.0018	6	0.28
L 20	100	3.93702	0.0007	180	7.08664	0.0012	2 3/8	5.0	0.20	3	0.12	0.0012	0.0018	6 1/16	0.32
L 21	105	4.13387	0.0007	190	7.48035	0.0012	2 3/16	5.0	0.20	3	0.12	0.0012	0.0018	6 5/16	0.32
L 22	110	4.33072	0.0007	200	7.87405	0.0012	2 3/4	5.0	0.20	3	0.12	0.0012	0.0018	7 1/4	0.35

[2]When a chamfer is used, it shall be 45 deg. from the axis of the bearing and ground true with the inside and outside diameters.
[3]The cage clearances are published as general information only.

TABLE 2—MEDIUM-SERIES METRIC ROLLER-BEARING DIMENSIONS

Bearing No.	Inside Diameter			Outside Diameter			Width, In. Plus or Minus 0.020	Radius or Chamfer[4] C				Eccentricity Tolerances of Races, In.		Cage Clearances, In.[5]	
								Max.		Min.					
	Mm.	In.	Tolerances in Inches Plus 0.0002 Minus	Mm.	In.	Tolerances in Inches Plus 0.0000 Minus		Mm.	In.	Mm.	In.	Inner	Outer	Diam.	Width
M04	20	0.78740	0.0006	52	2.04725	0.0008	7/8	1.5	0.06	1	0.04	0.0006	0.0012	1 3/4	0.20
M05	25	0.98425	0.0006	62	2.44095	0.0008	1	1.5	0.06	1	0.04	0.0008	0.0012	2 1/32	0.20
M06	30	1.18110	0.0006	72	2.83465	0.0008	1 1/16	4.0	0.16	2	0.08	0.0008	0.0012	2 1/2	0.20
M07	35	1.37795	0.0006	80	3.14962	0.0008	1 1/8	4.0	0.16	2	0.08	0.0008	0.0012	2 3/4	0.20
M08	40	1.57481	0.0006	90	3.54332	0.0008	1 1/16	4.0	0.16	2	0.08	0.0008	0.0012	3 1/8	0.20
M09	45	1.77166	0.0006	100	3.93702	0.0008	1 1/8	4.0	0.16	2	0.08	0.0010	0.0016	3 1/2	0.24
M10	50	1.96851	0.0006	110	4.33072	0.0008	1 3/4	4.0	0.16	2	0.08	0.0010	0.0016	3 13/16	0.24
M11	55	2.16536	0.0006	120	4.72443	0.0008	1 13/16	5.0	0.20	3	0.12	0.0010	0.0016	4 1/4	0.24
M12	60	2.36221	0.0006	130	5.11813	0.0008	2 1/16	5.0	0.20	3	0.12	0.0010	0.0016	4 5/8	0.24
M13	65	2.55906	0.0006	140	5.51183	0.0008	2 1/8	5.0	0.20	3	0.12	0.0010	0.0016	5	0.24
M14	70	2.75591	0.0007	150	5.90554	0.0012	2 1/2	5.0	0.20	3	0.12	0.0010	0.0016	5 3/4	0.28
M15	75	2.95277	0.0007	160	6.29924	0.0012	2 11/16	5.0	0.20	3	0.12	0.0010	0.0016	5 5/8	0.28
M16	80	3.14962	0.0007	170	6.69294	0.0012	2 11/16	5.0	0.20	3	0.12	0.0012	0.0018	6 1/16	0.28
M17	85	3.34647	0.0007	180	7.08664	0.0012	2 7/8	5.0	0.20	3	0.12	0.0012	0.0018	6 3/8	0.28
M18	90	3.54332	0.0007	190	7.48035	0.0012	2 7/8	5.0	0.20	3	0.12	0.0012	0.0018	6 5/8	0.32
M19	95	3.74017	0.0007	200	7.87405	0.0012	3 1/16	5.0	0.20	3	0.12	0.0012	0.0018	7 5/8	0.32
M20	100	3.93702	0.0007	215	8.46460	0.0012	3 1/4	5.0	0.20	3	0.12	0.0012	0.0018	7 11/16	0.32
M21	105	4.13387	0.0007	225	8.85830	0.0012	3 1/16	5.0	0.20	3	0.12	0.0012	0.0018	7 15/16	0.32
M22	110	4.33072	0.0007	240	9.44886	0.0012	3 5/8	5.0	0.20	3	0.12	0.0012	0.0018	8 5/16	0.32

[4]Where a chamfer is used, it shall be 45 deg. from the axis of the bearing and ground true with the inside and outside diameters.
[5]The cage clearances are published as general information only.

Tables 1 and 2 show the present S.A.E. Standards for light and medium series metric-type roller bearings as proposed to be revised. The tolerances for the inside and the outside diameters are as now specified in the present S.A.E. Standard. At the meeting in 1918, however, it was proposed that further consideration be given to these tolerances as they depend upon the type of bearing and its application.

Transmission Lubricating Oil

At the Joint Conference of the Interdepartment Petroleum Specifications Committee, the Advisory Committee on Petroleum Specifications and Methods of the American Petroleum Institute and the Society's Lubricants Division in the City of Washington on Nov. 13, 1922, the recommendation for transmission lubricating oils published in the November, 1922, issue of THE JOURNAL, was discussed. The principal objections were that the flash-point is too high and the pour-test value too low for the summer grade. It was also thought that the specifications might be broadened to include other grades of oil. The proposal was referred back to the Lubricants Division and was therefore discussed at a subsequent meeting of the Division. It was decided that the Standards Department should circularize the industries for further information and suggestions as to the specifications.

Sheet Steel

As the American Society for Testing Materials and the Detroit Chapter of the American Society of Steel Treaters have appointed Subcommittees on sheet-steel standardization, it has been arranged to hold joint meetings of these committees and the Iron and Steel Division's Subdivision on Sheet Steel. The dividing line between steel strip and sheet not being clearly defined, it has been decided that the Society's Sheet-Steel Subdivision shall be known as the Subdivision on Steel Sheets and Strips and cover both materials in its report.

RESEARCH REDUCES HIGHWAY COSTS

THE second annual meeting of the Advisory Board on Highway Research was held on Nov. 23 and 24 at the National Research Council headquarters in the City of Washington. This Board serves as a coordinating agency for the highway activities of the Country and is a subsidiary of the National Research Council. At the meeting the national highway-transport problem was discussed from various angles, but particular attention was given to its economic aspects.

Obviously, highways can no longer be classed as "good roads" or "bad roads." The commercialization of highway transportation of both freight and passengers in the past few years has led to a general recognition of the highway, not as ministering to the pleasure and comfort of the user, but as an essential part of a great economic whole, namely a system of transportation parallel in importance to railways and water routes.

It is a surprising fact that while the cost of highways is scarcely more than five per cent of the total cost of highway transportation, and vastly less than the cost of vehicles and their accessories, yet the recognition of highway transport as a single great economic problem has to be credited to the highway engineer, while the automotive industry, if we may judge from its public activities, has not yet even grasped the full significance of this problem.

The meeting was attended by about 100 representatives of the member societies and others, and the program occupied the full day Thursday, the 23rd. On Friday the delegates visited the experimental station of the Bureau of Public Roads at Arlington Farm, across the river from the City of Washington, and the laboratories of the Bureau of Standards. Among the most interesting exhibits at the former were a new type of impact testing-machine to determine the effect of wheel action on the road and two circular test-tracks, one of bituminous material and the other of concrete, for the study of surface wear, corrugation and the like. At the Bureau of Standards, where various automotive and highway problems are being studied, was a newly developed instrument for recording the performance of cars on the road and apparatus for the testing of tires under various conditions for power requirements and durability.

The technical session included reports from the subcommittee on Economic Theory of Highway Improvement, Structural Design of Roads, Character and Use of Road Materials, Highway-Traffic Analysis, Highway Finance and Maintenance, and from some of the member societies.

The report of the Director, Dr. W. K. Hatt, outlined the present status of highway research and described the tasks that lie ahead. It dealt particularly with the progress made by the Advisory Board on Highway Research, the needs of the Board to accomplish its purpose, the activities of the Director, and the notable researches carried out in the highway field during the year.

The report of Prof. T. R. Agg, of the Committee on the Economic Theory of Highway Improvement, was of particular interest. This covered a research project that has been in progress at Iowa State College for two or three years and is now substantially completed. The tests were designed to determine the relative fuel-consumptions and tractive-resistances of various types of vehicle on different classes of road. Most of the measurements were made by a time and distance recording device, though at least two types of accelerometer were used for part of the work.

The conclusions shown were as follows:

(1) About half the fuel consumed by a motor car or truck is required to operate the mechanism and to overcome air resistance

(2) Unevenness of surface is immediately reflected in an increase in tractive resistance

(3) A change to a better type of highway surface may easily save enough fuel to liquidate the cost of the improvement

(4) Bituminous-type roads show materially higher resistance in hot than in cold weather

(5) Rolling resistance on low-grade roads is an exceedingly variable quantity

The report of Dr. A. T. Goldbeck, of the Bureau of Public Roads, described briefly the recent experimental work at that bureau and explained the results obtained by recent tests that will permit a decrease in the cost and an increase in the strength of some types of road, notably concrete constructions. This paper gave the impression that, in contrast to the situation a year ago, design factors for highways are coming to be well understood.

The papers by H. S. Mattimore, G. E. Hamlin, J. G. McKay and W. H. Root were all of importance in their respective lines. The evening session commenced with a paper by Dr. Raymond Dodge on the Services of Psychology to Problems of Traffic Control. Professor Dodge treated the problem of traffic control in a new and interesting way, emphasizing its psychological and physiological elements to the exclusion of the mechanical ones. He discussed the mental reactions of the driver and the pedestrian under conditions of traffic and suggested a number of possible changes in the regulations to take these factors into account. In discussing the various types of highway sign, he emphasized the necessity of signs that the driver can understand instantaneously. He expressed the opinion that explanatory matter in smaller type is likely to distract attention momentarily from the main idea and thus become a source of danger.

Dr. H. C. Dickinson, of the Society of Automotive Engineers, explained briefly the organization of its Research Department and described some of the projects that are being handled by this department. He outlined some of the more interesting and urgent highway problems that concern the automotive industry, notably that of internal power-losses in vehicles and their effect on the rate of fuel-consumption; the effects of road surfaces on the maintenance cost of the vehicle; elimination of the danger of skidding; efficiency of brake action as affected by the road surface; and general questions of traffic control.

W. S. James, of the Bureau of Standards, described some of the recent work done there, including a newly perfected instrument for measuring and recording the various factors of vehicle performance on the road. The records taken include instantaneous fuel-consumption, acceleration and deceleration; instantaneous speed in steps, from which time-distance records can be deduced, as well as pressures in the intake-manifold, as an index of engine power; other pressures and temperatures at various positions, and the speed and direction of the car with reference to the air and wind. In total, 17 separate records are kept continuously and automatically in a form convenient for analysis, all but the fuel-consumption record being on a single sheet of paper.

In the absence of Major M. L. Ireland, a very brief summary of the Quartermaster Corps Tractive Resistance of Roads Research was given by Dr. Dickinson. This project has been under way for about a year and a half, and the experimental program is complete. Studies have been made of the rolling-resistance of five different vehicles with loads of from 0 to 200-per cent normal, and at speeds of from 5 to 25 m.p.h., on a variety of roads. These tests include observations with a traction dynamometer, a Wimperis recording accelerometer and a newly designed recording accelerometer of another type. Some 550 separate tests were run in all.

In addition to these runs, tests of rolling-resistance under various loads with a number of different classes of tire, pneumatic and solid, were made on a drum dynamometer in the laboratory at Sheffield Scientific School by Professor Lockwood. The results of these have already been published.

The research program also includes about 90 tests of sliding friction of tires on various classes of road surface. The results are now being compiled by a subcommittee of the Advisory Board on Highway Research.

SOCIETY MEETINGS

ANNUAL MEETING PROGRAM

TUESDAY, JAN. 9

10:30 a.m.—STANDARDS COMMITTEE SESSION

2:00 p.m.—STANDARDS COMMITTEE SESSION (Continued)

2:00 p.m.—BODY ENGINEERING SESSION

*Testing of Paints and Varnishes.....L. V. Pulsifer
Presentation Includes Actual Laboratory Demonstrations

*The Needless Hardwood Lumber Waste....F. F. Murray

8:00 p.m.—AERONAUTIC SESSION

Symposium of Five Papers on the Design of Commercial Airplanes, Followed by Prearranged Discussion

WEDNESDAY, JAN. 10.

10:00 a.m.—ANNUAL BUSINESS MEETING

Address by President Bachman
Reports of Officers and Committees
Election of Officers
A Critical Study of Modern Steering Systems,
Herbert Chase

2:00 p.m.—DETONATION SESSION

*Engine Characteristics Under High Compression.
J. H. Holloway, H. A. Huebotter and G. A. Young

The Laws Governing Detonation....Thomas Midgley, Jr.

*Testing Fuels for High-Compression Engines.
Stephen M. Lee and Stanwood W. Sparrow

2:00 p.m.—BODY ENGINEERING SESSION

Reducing the Cost of Enclosed Bodies..George J. Mercer
Testing of Leather Substitutes.....J. B. Davis

THURSDAY, JAN. 11

10:00 a.m.—RESEARCH SESSION

*Report and Results of S.A.E.–A.P.I.–N.A.C.C. Fuel-Volatility Research at Bureau of Standards
Papers by Dr. H. C. Dickinson, W. S. James and R. E. Carlson. Also Report on Automotive Highway Research

2:00 p.m.—FUEL SESSION

Further Data on the Effective Volatility of Motor-Fuels,
Robert E. Wilson and Daniel P. Barnard, 4th

*An Experimental Survey of Gasoline and Kerosene Carburetion.....C. S. Kegerreis and G. A. Young

6:30 p.m.—ANNUAL DINNER, HOTEL PENNSYLVANIA

C. F. Kettering, Toastmaster
Presentation of Collier and Mackay Aeronautical Trophies
Address by Elisha Lee, Vice-President Pennsylvania Railroad
The Motor Truck and Our Railroads—A Problem of Co-ordination

FRIDAY, JAN. 12

10:00 a.m.—ENGINE COOLING SESSION

*Air-Cooled Passenger-Car Engines,
S. D. Heron, C. F. Taylor and E. H. Dix, Jr.

*Cooling Capacity of Automobile Radiators,
E. H. Lockwood

*Papers marked with an asterisk are printed in full in this issue of the JOURNAL.

NEW YORK MEETING PROGRAM

Valuable Papers on Fuel Carburetion, Steering, Engine-Cooling, Airplanes and Body Design

DISCUSSION of the problems encountered in the use of fuels of comparatively low volatility will feature the technical sessions at the Annual Meeting, Jan. 9 to 12 in New York City. The results of the Fuel-Volatility Research project fostered by the Research Department of the Society will be set forth in official reports and analyses to be presented by Dr. H. C. Dickinson and members of the Bureau of Standards staff. One entire session will cover the topic of detonation and engine characteristics under high compression; another session will include a very comprehensive paper on carburetion. The detailed program of the meeting is printed on this page and it will be noted that a number of the complete papers are printed in this issue of THE JOURNAL.

THE BODY ENGINEERING SESSIONS

Two sessions on body engineering matters are a part of this year's program. The paper on Testing of Paints and Varnishes will be accompanied by laboratory demonstrations of the methods discussed in the paper. Reduction of the cost of enclosed bodies is a matter of current interest among body engineers and the paper by George J. Mercer will describe an unconventional type of construction that is sure to affect the closed body design practice of the future. Artificial leather and top material replace practically all of the metal panels in this novel construction. The testing of these materials has been a problem of some concern to body engineers; methods are unstandardized and the results cannot be uniform. This matter has received the study of many body and production men and some experience will be presented by J. B. Davis.

REFINEMENT OF STEERING MECHANISM

The paper by Herbert Chase which follows the Business Meeting makes a critical analysis of the faults in steering mechanism that result in wheel wobble, hard steering and excessive play. Designs of steering-gears are studied and tabulated data are presented for reference purposes.

The result of the ballot for 1923 officers of the Society will be announced in the Business Meeting. President Bachman will address the meeting and graphic reports of the meetings, sections and membership activities of the Society will be shown by stereopticon.

The two papers to be given in the Friday meeting are published in this issue of THE JOURNAL. Air-cooling enthusiasts will find Mr. Heron's paper a very able treatise on this type of engine and one certain to result in a valuable discussion. Professor Lockwood's paper presents quantitative data on radiator capacity in a form that makes them readily applicable in design work.

COMMERCIAL AIRPLANES TO BE CONSIDERED

It is the purpose of the Aeronautical Meeting on Tuesday evening, Jan. 9, to promote an informal discussion of the characteristics of a freight-carrying airplane. It will be a discussion of practical design features as related to the economics of operation. Four or five short papers will be read to open the discussion, but the latter is expected to consume the major part of the meeting period. Prof. E. P. Warner, V. E. Clark and W. L. Gilmore have agreed to submit introductory papers and others are expected.

All of the technical sessions will be held in the Engineer-

ing Societies Building, 29 West Thirty-ninth Street, New York City. The morning meetings will start at 10 o'clock and those in the afternoon at 2 o'clock. It is the practice of the Society to start all meetings promptly at the hour set. Members who are tardy will lose just that much of the program.

RAILROAD FARES REDUCED

Saving Will Pay Member's Dues in Many Cases

The members of the Society who will attend the New York City and Chicago meetings can purchase railroad transportation at a substantial reduction in cost. The saving will be sufficient in many cases to pay the member's annual dues to the Society. This privilege is limited to members of the Society and dependent members of their families. Please note the following directions carefully:

(1) Buy tickets to New York City between Jan. 4 and 10; buy tickets to Chicago between Jan. 25 and 31

(2) Ask the agent for a *Reduced-Fare Certificate*, not a receipt

(3) Present signed certificate for validation at S. A. E. Transportation Desk, 29 West Thirty-ninth Street in New York City, Hotel Congress lobby in Chicago, immediately upon arrival in the city

(4) Certificates will be validated Jan. 10 and 11 in New York City and Jan. 31 and Feb. 1 in Chicago. Do not plan on returning before these dates as no certificates can be validated before 250 have been received. Arrive before the dates given since no certificates can be validated at later dates

(5) Validated certificates entitle you to one-half fare returning over the same route as you came, if purchased before Jan. 17 in New York City or Feb. 7 in Chicago

(6) Reduced-fare returning tickets are not good on certain limited trains. Consult the agent regarding this

(7) It must be understood that the reduction on the return journey is *not* guaranteed, but is contingent on the attendance of not less than 250 members and dependent members of their families

(8) The Society is held accountable under the Interstate Commerce laws for any violation of the agreement limiting the reduced-fare privilege to members and dependent members of their families. Regardless of any assurance given by local railroad officials or others, absolutely no certificates will be validated unless they are presented by persons whose membership is evidenced by our records. Applicants for membership are not construed as members

The reduced-fare plan applies from stations in all States except Oregon, Washington, California, Nevada, New Mexico and Arizona. Members living in the States named may purchase tickets at regular rates to the nearest station from which reduced-fares apply and then are able to buy transportation from that station to New York City or Chicago at the reduced rate.

RAILROAD EXECUTIVE TO SPEAK

Elisha Lee Favors Coordinating Rail and Truck Transport

The Annual Dinner of the Society will be held at the Hotel Pennsylvania, Jan. 11 at 6.30 p. m. Elisha Lee, vice-president of the Pennsylvania Railroad, will address the members on The Motor Truck and Our Railroads, a Problem of Coordination. Mr. Lee is in charge of operation of the Eastern lines of the Pennsylvania System. His topic reflects his belief that the motor truck can become a valuable ally of the railroad in the transportation of the nation's goods.

C. F. Kettering has agreed to preside as toastmaster at the annual dinner, a responsibility that seems to fall upon his shoulders with annual regularity. None will regret the recurrent choice of Mr. Kettering as guide of the dinner, for this assures an ample supply of humor on the occasion of the society's most representative gathering. President Bachman and Herbert W. Alden, Presidential nominee, will address the members during the Dinner.

Application blanks for Dinner tickets reached all members in a recent issue of the *Meetings Bulletin* and also as a part of p. 551 of the December issue of THE JOURNAL. Reservations are being received in gratifying numbers and undoubtedly the attendance will equal that at the 1922 Dinner.

RADIO BROADCAST OF SPEECHES

WJZ Will Transmit Annual Dinner Program from New York City

The speeches at the Annual Dinner of the Society in New York City will be broadcasted by radio-phone from station WJZ of the Westinghouse Electric & Mfg. Co. at Newark, N. J. Microphones installed in the ball-room of the Hotel Pennsylvania will carry the words of the dinner speakers to listeners throughout a large section of the country, including most of the automotive manufacturing district. Station WJZ broadcasts on a wave-length of 360 m. and has recently been equipped to carry its programs well beyond the Mississippi River. By this popularized achievement of scientific and engineering genius it will be possible for members of the Society to enjoy the Annual Dinner program in their homes at far-distant points. Truly this is a century of marvelous engineering progress!

The exact time-schedule of the radio program will be published in an issue of the *Meetings Bulletin* that will reach the members about Jan. 3. Watch for this schedule and arrange to have your friends enjoy the Annual Dinner program with you.

NAVY AIRSHIP INSPECTED

Pennsylvania Members View Framework of the ZR1

The duralumin framework of the huge Navy rigid airship ZR1 was inspected by a group of Pennsylvania Section members at Lakehurst, N. J., Dec. 19. The spacious airship hangar, or dock as the Navy men term it, and the tall steel mooring mast were also shown to the visitors. Following the inspection, Com. R. D. Weyerbacher gave a short talk on the engineering features of the ship and explained why the Navy decided to design and construct the ZR1 in the face of the adverse public opinion resulting from the ZR2 and the Roma disasters.

The ZR1 follows German Zeppelin practice in its general design although many of the details are altered in accordance with the lessons learned from the ZR2 failure and the results of recent research work of Navy engineers. The ship will displace 2,290,000 cu. ft., will be 680 ft. long and 78 ft. wide, and will attain a maximum speed of 65 m.p.h. She will be driven by six six-cylinder 300-hp. Packard engines designed especially for airship service. These engines have attained a fuel economy of 0.43 lb. per b.hp-hr., which compares with 0.55 lb. per b.hp-hr. for the Liberty engine. Two engines drive their propellers direct, but the other four drive through a reduction gear; one pair of engines is geared so that the propeller rotation may be reversed.

Extreme care is being taken in the fabrication of every detail piece of the ship and in the final assembly, for the Navy realizes that the success or failure of the ZR1 will determine the future of lighter-than-air ships in the minds of the public. Every precaution has been taken to avoid structural failure and a board of the National Advisory Committee for Aeronautics recently approved the design as safe.

FIRE RISK MINIMIZED

Commander Weyerbacher stated that fire risk in the ZR1 has been reduced to a minimum. Some airship fires in the past have been caused by leaking oxygen being ignited by discharges of static electricity at the point of leakage. The Germans have considered the rubber present in the gas bags or the external envelope responsible for the presence of this

static electricity. They eliminated all rubber from the gas bag covering by perfecting a special cement, the formula of which has remained a secret. Since the use of this cement, German airship fires have disappeared. The Navy is working toward the perfection of a similar cementing material and eventually hopes to eliminate all rubber in the gas bags.

Helium Used for Trial Flights

The ZR1 is expected to make her first flight about July 15. Helium will be used during the trials to insure against any danger of fire from this source. The officers and engineers at the Lakehurst station do not favor the use of helium because it is roughly 30 per cent heavier than hydrogen and lowers the useful-load capacity of the ship an equal percentage. It is their belief that all airship fires have been the secondary result of some avoidable primary cause such as structural weakness or a collision.

The Pennsylvania Section has scheduled a meeting on Lubrication for the evening of Jan. 25 at the Philadelphia Engineers' Club.

SERVICE CHICAGO FEATURE

Society Meets on January 31 to Discuss the Flat-Rate System

Two papers will be presented at the Chicago Meeting of the Society setting forth the actual experience of automotive engineers who have made successful applications of the flat-rate system of conducting automotive service-stations. Don T. Hastings, formerly assistant chief engineer of the Hupp organization, will read a very complete paper on systems of repair and maintenance which he has successfully developed in his present role of Hupp dealer. Otis C. Funderburk, who is a Lincoln-Ford dealer in Boston, will describe some unusual accomplishments in applying engineering analysis to the reduction of repair costs.

Another important phase of service work will be treated by J. F. Page, of the Packard-Chicago Service organization, who will read a paper on Service Cooperation between the Manufacturer and the Dealer. Additional papers are expected on matters of interest to engineers engaged in the service branch of the industry. These papers will be read at a morning and an afternoon technical session to be held at the Congress Hotel, starting at 10 and 2 o'clock respectively.

The annual Chicago Dinner of the Society will be held at the Congress Hotel on the evening of the same day, Jan. 31, starting at 6.30 o'clock. *Godfrey H. Atkin* will be master of ceremonies in the official capacity of toastmaster. The single address of the evening will be given by a man prominent in the automotive industry. Seats for the dinner may be ordered now. Use the coupon on p. 52 of the advertising section of this issue of The Journal.

As stated in another column, reduced-fares are available to most of the members who will attend the Chicago Meeting. Be sure to avail yourself of the lower fares as an opportunity to attend the Automobile Show, the Service Meetings and the Chicago Dinner at a minimum of expense.

MECHANICS POORLY TRAINED

Repair Operations Must Be Simplified for This Reason

In an address before the Cleveland Section on Dec. 15, Paul Donavan presented a service-man's views on troubles to which automobiles are subject in the hands of the average owner.

The important theme stressed was the fact that while the engineer or production man or service-man might all be trained to the last notch, it must be remembered that a very large percentage of our automobile mechanics in the average garage are poorly trained and comparatively ignorant as regards the work they have to do. For this reason, Mr. Donavan believed that certain repairs had to be made easy for them, and he cited specific cases where simple trouble on an automobile could be cured only by very complicated operations. For example, on some cars it is necessary to dismantle a large portion of the engine before being able to grind the valves. Mr. Donavan spoke particularly of the matter of flywheel mounting on cars and the marking of valve opening and closing, claiming that the latter were very indistinct and indeterminate. He also brought up specific cases where lubrication facilities either were not provided or were at inaccessible points.

The discussion brought out some disagreements with Mr. Donavan but, on the whole, his main thesis was agreed upon. It was pointed out that it would be advisable to consider the instruction book very carefully, inasmuch as it should be made very plain, very clear and should not be written above the heads of the average mechanics. It should also be plentifully illustrated with diagrams that actually show the part of the car as it is seen by the user.

Railroads and Highways

The Railroads and the Highways, and Economical Transportation thereon, will form the subject of a paper to be read before the January meeting of the Cleveland Section by Charles O. Guernsey. This meeting will be held on the evening of Jan. 19 in the rooms of the Cleveland Engineering Society, Hotel Winton, and will be preceded by an informal dinner at 6:30 p.m. All members in the Cleveland district are invited to attend.

REMARKABLE TRUCK ECONOMY

H. L. Horning Describes Tests Claiming 100 Ton-Miles per Gal.

Tests of a motor truck that attained a fuel economy in excess of 100 ton-miles per gal. were described in papers given by H. L. Horning and James B. Fisher before a meeting of the Mid-West Section on Dec. 20 in Milwaukee. The 2½-ton truck tested was fitted with a four-cylinder engine, of 4-in. bore and 5½-in. stroke, especially designed to attain maximum thermal efficiency and economy. The total weights of the vehicle and the load ranged between 8300 and 16,000 lb. The chassis was fitted with a van body having a frontal area of approximately 40 sq. ft. A standard transmission, double-reduction axle and solid tires were used throughout the tests.

Mr. Fisher stated that the engine used had a minimum fuel-consumption of 0.48 lb. per b.hp-hr. and that the axle reduction had been selected to insure the operation of the engine through its range of greatest economy. Two routes were used for the test; one traversed typical country roads for a distance of 24 miles; the other route ran through city streets for 4 miles and included about a dozen stops. The country runs were made at a speed of 15 m.p.h. and those in the city at 12 m.p.h.

Steam Cooling System Used

A system of engine cooling was used where the cooling water is allowed to boil in the engine jacket and the steam drawn off and condensed in the radiator. Jacket-water temperatures of from 190 to 200 deg. fahr. are maintained with this system and Mr. Fisher stated that it resulted in better thermal efficiency, an increase of 8.8 ton-miles per gal. in economy, and allowed an increase in the compression-ratio because of a more uniform cooling of the cylinder. Special aluminum pistons were employed and these, in combination with a combustion-chamber form that promoted turbulence, allowed the compression-ratio to be raised to 5.5 to 1 without detonation being present. This higher compression resulted in a further increase in economy of 17.5 ton-miles per gal. The engine valves were arranged to turn slightly with each upward movement of the valve so that they were cooled more uniformly. This added another increase in economy of 5.5 ton-miles per gal.

Economy Result of Many Refinements

After all of these refinements were made, the truck with a load sufficient to bring the total weight to 16,000 lb., ran 89.6 ton-miles per gal. over the city course and 115.3 ton-miles per gal. over the country course, according to Mr.

Fisher. This remarkable economy was due to proper coordination of the units in the truck, increased thermal and mechanical efficiencies of the engine because of its higher jacket-water temperature and the employment of special forms of piston and combustion-chamber to allow the use of higher compression.

H. L. Horning presented an analysis of the causes of detonation and explained how these theories had been applied to the design of special combustion-chamber forms, piston types and spark-plug locations to reduce the possibility of detonation in the particular engine used in the economy test.

The Mid-West Section will hold a luncheon and brief meeting on Tuesday, Jan. 16, at the Chicago Engineers' Club at 12 o'clock. The committee that will choose the regular ticket of Section officers for 1923 and 1924 will be elected and reports of the various standing committees will be presented.

STEEL MANUFACTURE SHOWN

Minneapolis Section Also Hears Talk on Patterns

The complete process of steel manufacture was depicted in an educational motion picture shown to the members of the Minneapolis Section at their meeting of Dec. 6. The pictures were taken in the mills of the Interstate Iron & Steel Co. Prof. Peter Christianson of the University of Minnesota explained each of the manufacturing steps as the pictures were displayed and this added materially to the educational value of the meeting.

Design considerations in pattern and foundry practice were the subject of a talk given by R. C. Hitchcock. Examples of good and bad designs of castings were sketched and discussed, Mr. Hitchcock citing the cases causing trouble most frequently for the pattern maker and foundryman.

The next meeting of the Minneapolis Section has been arranged for Jan. 3. H. L. Bollum, president of the Twin City Motorbus Co., will speak on the Operation of City and Country Bus Service in Minnesota. A. J. Scaife, consulting engineer of the White Motor Co., is also expected to contribute a paper.

PISTON-RING DEVELOPMENT

Forms Topic of Washington Section Meeting

Multiple-piece piston-rings are losing favor rapidly, according to Allen W. Morton, who addressed the meeting of the Washington Section on Dec. 8. This is because of their greater liability to breakage, poor wearing quality in service and difficulty of installation. Individually cast rings are superior to pot-cast rings because of their uniformity, closer grained metallic structure, longer life and greater resiliency. Foundry practice of molding, melting and pouring is of greater importance than the chemical composition of the iron. Mr. Morton discussed methods of producing tension in rings and favored the practice that effects the result by artificial means such as peening, believing this assures better control of the final pressures on the cylinder-wall. He described a method of determining cylinder-wall pressures of rings by lapping a sample ring to produce rapid wear and then measuring the amount of ring wear at numerous points on the periphery. The importance of ring fit in the piston groove was stressed as a means of preventing oil-pumping.

It was brought out in the discussion that the present tolerance of from 0.001 to 0.005 in. in the width of rings might be confined to 0.0005 in. as a maximum and 0.0002 in. as a minimum. This, of course, would only be practical provided the piston manufacturers could standardize the width of the ring-grooves and confine their tolerances to a lesser limit than they do now. It was also brought out by Mr. Morton in discussion that nearly 90 per cent of the finished rings are now lathe turned, and hardly more than 10 or 15 per cent ground, whereas just the reverse of this was true 4 or 5 years ago. Mr. Morton expressed a preference for the turned rather than the ground ring. He had found oil-pumping less frequent in engines where well seasoned gray-iron rings of the plain type were used and properly treated to secure a uniform tension, best results being secured with three rings at the top of the piston and a fourth ring in the skirt.

Motor-Truck Transportation

The next meeting of the Washington Section will be held at the Cosmos Club on Jan. 5. Major Brainerd Taylor will read a paper on the Emergency Motor-Transport Plan in the United States Army. A second paper will be read by W. P. Eno on the Engineering Aspects of Traffic.

BOSTON MEETING ON SERVICE

Packard Executives Address New England Section of Society

Flat-rate service charges were discussed very fully at the New England Section meeting in Boston on Dec. 21. Knox Brown, service manager of the Boston Packard service-station, gave the principal paper. A representative of the Packard factory participated in the program and outlined the manner in which the factory supported the dealers in their efforts to render satisfactory maintenance service to the car-owner.

Recent Development of the Induction Magneto will be the topic of the next meeting of the New England Section on Jan. 25. The paper of the evening will be read by E. A. Robertson, chief engineer of the Splitdorf Electrical Co.

SCIENTIFIC WORK IMPORTANT

Physicists to Be Strong Influence in Automotive Development

Scientists and physicists will influence a large part of the automotive development of the future. This is the belief of J. H. Hunt, electrical engineer of the General Motors Research Corporation, who addressed the Indiana Section on Dec. 14. Mr. Hunt defined pure science as contrasted with engineering. The scientist works as an individual, his assistants being of a type that does not compare in mentality or training to the man himself. The scientist studies his problem, the apparatus to be used and frequently invents mathe-

Schedule of Sections Meetings

JANUARY

3—Minneapolis Section—Operation of City and Country Bus Service—H. L. Bollum
5—Washington Section—Emergency Motor-Transport Plan in the Army—Major Brainerd Taylor
The Engineering Aspects of Traffic—W. P. Eno
16—Mid-West Section—Business Meeting and Luncheon
18—Buffalo Section—Informal Dinner
19—Cleveland Section—Railroad and Highway Transportation—Charles O. Guernsey
25—New England Section—Recent Developments of the Induction Magneto—E. A. Robertson
25—Pennsylvania Section—Lubrication Meeting
Dayton Section—No meeting in January
Detroit Section—No meeting in January
Indiana Section—No meeting in January
Metropolitan Section—No meeting in January

matics to aid in the solution. He does not count the cost in time or money; the fact that it may take his lifetime to solve a problem does not discourage him. The scientist publishes everything he does just as soon as he is certain of the accuracy of his results; he is known by what he publishes and is very certain of his statements and conclusions.

The work of the engineer, in contrast, is done as part of an organization. He seldom gets credit for his work, especially during his early years. The engineer must count the cost in time and money; he is required to secure a result in a specified time. When an engineer has perfected a mechanism he is seldom at liberty to publish its details, for such publication is controlled by the patent and sales executives.

Mr. Hunt predicted that scientists would develop new and better engineering materials in the future. He believed that the engineers will adopt the scientist's method of work in the next decade. The importance of testing details rather than assembled units will be appreciated. When one wishes to study a carbureter, it will be tested individually as a carbureter, not as a part of the entire engine system. There will be constantly increased cooperation between the engineer and the scientist, fewer accidental discoveries will occur and automotive engineering will be more generally based on scientific investigation and analysis.

The Indiana Section will not hold a meeting in January because of the possible conflict with the national meetings of the Society and the shows.

FUEL TESTS DESCRIBED

The Detroit Section was addressed by H. M. Rugg of the Dodge Bros. engineering staff at its meeting on Dec. 21. Mr. Rugg described the methods being employed by the Bureau of Standards in making the series of fuel-volatility tests for the cooperative fuel-research program fostered by the Society. Mr. Rugg was assigned by Dodge Bros. to assist in the work at the City of Washington and acted as observer on a majority of the tests.

The Detroit Section has announced that no engineering meeting will be held in January. There is a possibility that a meeting will be arranged on a subject of joint interest to production and designing engineers.

BETTER ENGINEERING NEEDED

Professor Upton of Cornell University Urges Lighter Weight Design

The Buffalo Section members enjoyed a very interesting paper by Prof. G. B. Upton on the occasion of the Section meeting of Dec. 15. Professor Upton's paper suggested means of applying the results of testing materials to the design of lighter automobile chassis. He believed that the body structure should be made an integral part of the chassis assembly in order that the roof or top would add to the rigidity of the entire unit. The high-speed engine will not be the ultimate type, in Professor Upton's opinion. He favors the use of carbon-steel in automobile frames since the primary requisite is rigidity and frames of deep section are amply strong without employing expensive alloy-steels.

The discussion of the paper brought out several opinions that are worthy of note. David Fergusson concurred with Professor Upton's belief that carbon-steel can be substituted for alloy-steels in many places without sacrificing strength to a serious degree. He cited the case of crankshafts where diameters have been steadily increased to resist torsional vibration with a consequent increase in their strength that will allow the substitution of carbon-steel for the expensive alloy-steels previously required. Otto M. Burkhardt was not certain that all tops could be made permanent, for there is still a demand for open bodies with folding tops in the warmer regions of the world.

The Buffalo Section officers are arranging an informal dinner for all members in the Buffalo district to be held during January. The date is set for Jan. 18 and other details will be mailed to the members later.

AIR-COOLED ENGINES

Franklin Engineer Presents Design and Performance Data

The important engineering features of the Franklin air-cooled engine were the subject of a talk given by C. P. Grimes, research engineer of the H. H. Franklin Mfg. Co., before the Metropolitan Section on Dec. 14. Mr. Grimes explained in detail the construction of each of the important engine and chassis units, emphasizing in each instance the points peculiar to the air-cooled design.

The cylinders of the engine have a total fin radiation surface of 650 sq. in., there being a total of 52 sheet steel fins, each 5 in. long, cast into the cylinder barrel. The length, the spacing and the number of the fins were arrived at after much experimenting. Mr. Grimes warned that there could be more and longer fins inserted but there would not be sufficient air passing by them to increase the cooling effect. Passages must be made large enough to avoid clogging with insects, dirt or other obstructions often encountered in cross-country driving.

The compression in the Franklin engine is about 72 lb. per sq. in. at the period of maximum torque; the brake mean effective pressure reaches a maximum of 77 lb. per sq. in. The air passing over the cylinders rises in temperature about 100 deg. fahr., keeping the cylinder-heads below a maximum temperature of 400 deg. fahr.

H. M. Crane remarked in the discussion that the valves in air-cooled engines are less accessible than in the water-cooled types; it is almost essential that the heads be integral with the cylinder barrel, necessitating the removal of the entire cylinder to clean carbon deposits and grind the valves.

No meeting of the Metropolitan Section will be held during January because of the national meeting of the Society in New York City, Jan. 9 to 12. The series of meetings will resume in February.

CARBURETION DAYTON SUBJECT

The meeting of the Dayton Section on Dec. 19 was addressed by P. S. Tice of the Stewart-Warner Corporation. His topic was Utilization of Low-Grade Fuels in Automotive Engineering. Mr. Tice read a well-prepared paper that aroused a lively discussion, in which members of the McCook Field and General Motors Research organizations participated. Thos. Midgley, Jr., presented theories in explanation of the detonation phenomena, basing them on the results of his latest research work.

The Dayton Section has no meeting scheduled for the month of January.

Applicants *for* Membership

The applications for membership received between Nov. 15 and Dec. 15, 1922, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALLISON, FRED, electrical engineer and superintendent of power, Ford Motor Co., *Detroit.*

ANDERSON, CARL C., assistant comptroller, Republic Motor Truck Co., *Alma, Mich.*

BARTUSKA, JOHN F., engineer, Maremont Mfg. Co., *Chicago.*

BELLOWS, LYMAN H. Detroit sales office, Walden-Worcester, Inc., *Worcester, Mass.*

BUTZ, JOSEPH E., research engineer, General Motors Research Corporation, *Dayton, Ohio.*

CAMMANN, OSWALD, JR., engineer, Davis Sewing Machine Co., *Dayton, Ohio.*

CHRISTIE, M. G., wing commander, Royal Air Force, British Embassy, *City of Washington.*

COLLINS, W. D., assistant engineer, H. C. Stutz Motor Car Co., *Indianapolis.*

CORNFORTH, R. GARDNER, chief engineer, Nice Ball Bearing Co., *Philadelphia.*

CRAM, RAMON S., vice-president and general manager, Ramon S. Cram Industries Co., *Columbus, Ohio.*

DE LA VERGNE MACHINE CO., *New York City.*

DOWNES, GEORGE Q., JR., student, Ohio State University, *Columbus, Ohio.*

ELLEMAN, THOMAS H., research engineer, General Motors Research Corporation, *Dayton, Ohio.*

ERNST, OTTO, dentist and inventor, *Larchmont, N. Y.*

FAIRCHILD, JOHN GUTHRIE, assistant professor, Rensselaer Polytechnic Institute, *Troy, N. Y.*

FAY, CHARLES R., production supervisor, Weidely Motors Co., *Indianapolis.*

FISHER, R. B., student engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.*

FORBES, MYRON EDSON, vice-president and general manager, Pierce-Arrow Motor Car Co., *Buffalo.*

FORDHAM, THOMAS B., superintendent, Delco Light Co., *Dayton, Ohio.*

FREYMAN, ALEXANDER, draftsman, Western Electric Co., *New York City.*

GEISE, JOHN HARLIN, engineer, Aeromarine Plane & Motor Co., *Keyport, N. J.*

GREENE, LOUIS, student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

GUGLER, JULIUS H., vice-president, Globe Electric Co., *Milwaukee.*

GUTMAN, HARRY, design engineer, Advance-Rumely Co., *LaPorte, Ind.*

HARDIMAN, FRANK M., assistant to president, Harrison Radiator Corporation, *Lockport, N. Y.*

HAUTZENROEDER, RICHARD WAGNER, Aultman-Taylor Machinery Co., *Mansfield, Ohio.*

HINCHMAN, HERMAN H., assistant chief and road inspector, Lexington Motor Co., *Connersville, Ind.*

INGALS, E. FLETCHER, 2ND, student, Massachusetts Institute of Technology, *Cambridge, Mass.*

JONES, AUGUST F., student, Cornell University, *Ithaca, N. Y.*

KEDZIE, LAURENCE FYFE, manager of sales, eastern division, automotive department, Dahlstrom Metallic Door Co., *Jamestown, N. Y.*

LACEY, ARTHUR H., senior member, Arthur H. Lacey Co., *Los Angeles, Cal.*

LANDES, JAMES U., engineer, Standard Oil Co., *Portland, Ore.*

LATIMORE, D. S., student, Alabama Polytechnic Institute, *Auburn, Ala.*

LEWELLEN, A. R., electrical engineer, Chevrolet Motor Co., *Detroit.*

MCALLISTER, RALPH HAMMOND, detail draftsman, *Urbana, Ill.*

MANBECK, PARK D., brush sales engineer, National Carbon Co., Inc., *Cleveland.*

MASON, OSCAR E., foreman of block testing, International Motor Co., *Plainfield, N. J.*

MONTANYA, H. L., inspector and salvage supervisor, Moon Motor Car Co., *St. Louis.*

MOORE, IRA A., in charge of repair department, Reliance Mfg. Co., *Cedar Rapids, Iowa.*

MORGENSTERN, GEORGE H., general sales manager, automobile division, Bullard Machine Tool Co., *Bridgeport, Conn.*

MORRISON, J. B., assistant chief engineer, Durant Motors of Canada, *Leaside, Ont., Canada.*

MORTON, ANSEL N., department head, International Motor Co., *Plainfield, N. J.*

MURAKAMI, YOSHI-AKI, works manager, Ishikawajima Shipbuilding & Engineering Co., Ltd., Tokyo, Japan.

NAFZGER, EDWIN, designing engineer, Koppel Industrial Car & Equipment Co., *Koppel, Pa.*

PARCELL, EARL W., designing engineer, Fairbanks, Morse & Co., *Beloit, Wis.*

PARKER, GEORGE ARNOLD, designing engineer and draftsman, Witteman Aircraft Corporation, *Hasbrouck Heights, N. J.*

PECK, FRANK, superintendent, Iowa State Auto and Tractor School, *Sioux City, Iowa.*

PELTON, AYLMER E., draftsman, Union Construction Co., *Oakland, Cal.*

PLEUTHNER, CHARLES, passenger-car engineer, Pierce-Arrow Motor Car Co., *Buffalo.*

POLLITT, CAPT. ALLEN V., shop superintendent, Quartermaster Corps, *Camp Normoyle, Tex.*

RENOLD, HANS, INC., *New York City.*

SAMPLE, SAM STEELE, student, University of Illinois, *Urbana, Ill.*

SAWYER, GEORGE W., motor-vehicle supervisor, Detroit division, Sinclair Refining Co., *Chicago.*

SCHNEPEL, HERBERT, layout draftsman, Nordyke & Marmon Co., *Indianapolis.*

SHOEMAKER, FRED R., student, University of Illinois, *Urbana, Ill.*

SOKAL, EDWARD, vice-president and technical manager, Katalite Corporation, *New York City.*

SPARKS, CLIFFORD M., sales engineer, Sparks-Withington Co., *Jackson, Mich.*

SWENSON, HJALMAR S., aviation-engine mechanic, Air Mail Service, *Rock Springs, Wyo.*

TANAKA, TSUNESABURO, superintendent of body department, Yanese Automobile Co., Ltd., *Tokyo, Japan.*

TODD, CHARLES RUSSELL, assistant service manager, Olds Motor Works, *Lansing, Mich.*

TREVELYAN, HARRY A., assistant supervisor of inspection, Studebaker Corporation of America, *Detroit.*

USHIODA, SEIKICHI, student, Cornell University, *Ithaca, N. Y.*

VOLK, ALBERT, engineer, G. Elias & Bro., *Buffalo.*

WALTER, CHARLES TAYLOR, experimental engineer, Swift & Co., *Chicago.*

WHITEHEAD, J. FRAZER, secretary and treasurer, Kales Stamping Co., *Detroit.*

WILLIAMS, HOMER R., sales engineer, Aluminum Co. of America, *Detroit.*

WOLLERING, MAX F., vice-president, Studebaker Corporation of America, *Detroit.*

YACKEY, HAROLD HILGARD, student, University of Illinois, *Urbana, Ill.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Nov. 10 and Dec. 9, 1922. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ATANGAN, TOMAS T. (J) 3800 Grand Boulevard, *Chicago.*

BURNELL, E. (M) assistant to president, Overman Cushion Tire Co., 250 West 54th Street, *New York City.*

CIAFFONE, JAMES V. (J) president, Engineering Automobile School, 474 Steinway Avenue, *Long Island City, N. Y.*

DUNSMORE, R. B. (M) manager of plant, Security Mfg. Co., *Los Angeles, Cal.,* (mail) 4119 South Western Avenue.

FOISY, GEORGE A. (M) designing engineer, U. S. Cartridge Co., *Lowell, Mass.,* (mail) 1084 Bridge Street.

GILBERT, H. HOYT (M) research engineer, Cadillac Motor Car Co., Detroit, (mail) 171 Florence Avenue, *Highland Park, Mich.*

GLICK, PHILLIP P. (J) inspector, Moon Motor Car Co., *St. Louis,* (mail) 4145 Lindell Boulevard.

GOTTSCHALK, V. H. (M) research engineer, Society of Automotive Engineers, Inc., 29 West 39th Street, *New York City.*

HERMAN, F. P. (A) manager of factory sales, Houdaille Co., *Buffalo,* (mail) 1400 West Avenue.

HOWE, EARL E. (J) Baker Wheel & Rim Co., 659 Book Building, *Detroit.*

IRELAND, MAJOR MARK L. (S M) Quartermaster Corps, (mail) Room 10-219, Massachusetts Institute of Technology, *Cambridge, Mass.*

JACKSON, ELWELL RANSOM (M) automotive engineer, Rock Island Arsenal, Rock Island, Ill., (mail) 804 Kirkwood Boulevard, *Davenport, Iowa.*

KENNEDY, CAPT. GRAFTON S. (S M) Ordnance Department, Aberdeen Proving Ground, Aberdeen, Md., (mail) care Quadrangle Club, *Chicago.*

LEA, R. W. (A) executive vice-president and general manager, Stephens Motor Car Co., Inc., *Moline, Ill.*

MACKENZIE, RUSSELL E. (A) carburetor engineer, Detroit Lubricator Co., *Detroit,* (mail) 331 Chandler Avenue.

MACKIE, NORMAN S. (A) treasurer and general manager, Electrocar Corporation, 501 Fifth Avenue, *New York City.*

MACVICHIE, DONALD (A) industrial engineer, Motor Transit Co., Los Angeles, (mail) 1248 Gordon Street, *Hollywood, Cal.*

OHTSUKA, CAPT. N. (F M) Imperial Japanese Artillery, Tokyo Military Arsenal, Japan, (mail) care of Mitsui & Co., 65 Broadway, *New York City.*

ORR, ERNEST M. (M) assistant general manager, Oakland Motor Car Co., *Pontiac, Mich.*

PRICE, LEONARD C. (J) student, Cornell University, *Ithaca, N. Y.,* (mail) 102 Oxford Road.

PRODOEHL, H. G. (A) in charge of tool design department, tractor works, International Harvester Co., *Chicago,* (mail) 2135 Coulter Street.

RICK, EDWARD L. (A) engineer, H. S. Honigsberg & Co., Peking, China, (mail) 671 East 49th Street, *Los Angeles.*

SIMPSON, ALBERT F. (A) field representative in charge of Mexico and Central America, White Co., Paseo de la Reforma, No. 122, *Mexico, D. F., Mexico.*

SMITH, LEOPOLD J. (A) draftsman, American Railway Express Co., New York City, (mail) 728 Jassamine Way, *Grantwood, N. J.*

SMITH, T. D. (A) sales manager, Harvey Electric Co., Chicago, (mail) 1433 Rollins Road, *Toledo.*

STANLEY, THOMAS R. (A) general manager, Oil City Engine & Power Co., 401 West Third Street, *Oil City, Pa.*

STOREY, EDWIN F. (J) layout draftsman, Paige-Detroit Motor Car Co., *Detroit,* (mail) 3010 Harding Avenue.

SUTHERLAND, J. D. (A) general sales manager, Wyman-Gordon Co., Worcester, Mass., (mail) 941 Society of Savings Building, *Cleveland.*

TILLEY, NORMAN NEVIL (S M) aeronautical mechanical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 2046 Ravenwood Avenue.

TITCHENER, WALTER E. (M) production manager and engineer, Cortland forging division, Brewer-Titchener Corporation, *Cortland, N. Y.*

UPSTILL, EDGAR D. (J) experimental assistant, White Motor Co., Cleveland, (mail) 2683 Coventry Road, *Shaker Heights, Cleveland.*

WAHLBORG, EWALD G. (M) body draftsman and designer, Zeder-Skelton-Breer Engineering Co., Newark, N. J., (mail) 136 Coe Avenue, *Elizabeth, N. J.*

WOOLSON, HARRY THURBER (M) engineer, Zeder Motor Car Co., Newark, N. J., (mail) 8 Laurel Avenue, *Summit, N. J.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XII February, 1923 No. 2

Chronicle and Comment

Engineer and Salesman

THE engineer and the salesman ought to talk things over; they ought to have conferences and ride in machines together. There should be constant contact so that the engineer may know what problems develop as between the salesman and the customer.—George M. Graham.

The Meetings of 1923

THE attention of the members is directed to several important announcements in this issue of the JOURNAL relating to future meetings of the Society. A national meeting devoted to Automotive Transportation will be held at Cleveland in April. The location of the Summer Meeting will undoubtedly be in the East, probably at a seashore resort. The Production Meeting will be held at Cleveland during the month of October and will follow the plan that was so successful in Detroit last year. The technical sessions that have been a feature during the New York Show week are to be transferred to Detroit, in connection with the 1924 Annual Meeting. The reasons for these departures from precedent are given fully on p. 243; it is important that you be familiar with them.

Brake-Drum Standardization

TO determine the feasibility as well as the desirability of standardizing brake-drums, comments in reference to this question were recently solicited from passenger-car and motor-truck builders. Of the replies received, 33 companies were in favor of standardizing brake-drums as against 22 who were not in favor of such action. The objections to undertaking such standardization were based principally on the following reasons:

(1) The tendency toward the use of the 20-in. rim.
(2) The tendency toward the use of four-wheel brakes.
(3) The tendency toward the use of transmission brakes.
(4) The tendency toward the use of air and hydraulic brakes.
(5) The fact that brakes are not satisfactory as at present designed.

The comments have been sent to the members of the Axle and Wheels Division in abstracted form and will doubtless be of considerable aid in determining whether the standardization of brake-drums should be undertaken.

The Public Demands It

THERE is one group of people in this Country that favors the flat-rate service-system; they are the car-owners. Several men prominent in our industry have said that the car-owners are the real bosses of the automotive industry. If this be true, and logically it must be, then it is high time that flat-rate practice became universal. It is the Society's privilege to print in this issue of THE JOURNAL one of the most convincing and informative papers that has been written on modern service-systems. We refer to the paper by Don T. Hastings on p. 193. It is rather significant that the system outlined should have been devised and made practical by an engineer whose entire experience had been in the designing end of the business previous to his entering the service field. The forms, accounting methods and policies presented are the result of painstaking analysis, engineering analysis, and deserve the most careful reading, not alone by service-men, but by everyone having a sincere interest in the future of our industry and an appreciation of what the good-will of the car-owner means to designer, constructor and distributor alike. If the service or sales managers of your company do not receive THE JOURNAL, loan them this copy so that they may read Mr. Hasting's paper.

Differential Standardization

ON p. 229 of this issue will be found Chairman S. O. White's progress report on the work of the Differential Subdivision. That the work of this Subdivision is of real importance to every executive and engineer is well brought out in the following paragraphs quoted from a letter recently received from an executive well known to the industry.

> I can see no reason why a very satisfactory set of standards cannot be worked out, covering side gears, pinions and differential spiders, for both passenger-car and motor-truck axles. Such standardization is more important than the standardization of front-axle hubs because it would be more readily accepted by differential, axle and car manufacturers than would the stand-

ardization of hubs. Furthermore, it would result in a greater saving to the industry in general as there is absolutely no excuse for the large variation and the number of types of differential that are now being manufactured by the differential and axle manufacturers.

The recommendation of the Differential Subdivision was printed in full in the January issue of THE JOURNAL on p. 124. It is the desire of the Subdivision that users and manufacturers superimpose the proposed standard on their own axle designs on their drawing-board and from that base criticisms and suggestions which would be of assistance to the Subdivision in bringing the preliminary report into accord with the best present-day differential design.

The Industry

THE automotive industry within the space of its short manufacturing career has advanced until it is today third among the industries of the United States in value of annual output, affording annual employment to some 2,430,000 persons who earn their wage either in the output of the car itself or in producing the materials that go into the vehicle. About 600,000 are in the industry itself.

Today there are, in round numbers, 10,500,000 motor vehicles in the United States, or one to every 10 persons in the Country. The total world registration is but 12,500,000, so that it appears at once that 83 per cent of the cars now in use are in this Country. Of this total approximately 87 per cent are of American manufacture. No man can forecast fully the directions that the use of the motor vehicle will take. Each day finds some new place for it.

This development has brought in its wake new questions, or rather old questions demanding new answers. The advance in 10 years from 600,000 to 10,500,000 cars brings new requirements in methods, whether they be legislative, industrial or financial in nature. Only trained men can give us the key to their solution.

The motor vehicle has become a major unit in transportation, requiring minds of varied training in such fields as civil, chemical, mechanical, metallurgical and electrical engineering, economics, business administration and finance, research in physical and commercial lines and many other branches, including public service.

The industry will proceed rapidly or slowly according to the recognition that educators give to the magnitude of the educational need involved.—C. C. Hanch.

Highway Traffic

IN his last message to Congress, President Harding said that it may be expected that 20 years hence the population of this Country will be 150,000,000, or three times our recorded population in 1880. While, during the three decades ended in 1920, our population increased less than 30 per cent, the freight movement by railroad increased over 250 per cent. Our railroad mileage, which constitutes 40 per cent of that of the world, is inadequate for our present requirements.

The problem is enormous. In the words of our chief executive, we face transportation costs that much of the traffic cannot bear, and we must plan to coordinate all transportation facilities, turning the motor truck into a railroad feeder and distributor. The motor car must be applied to its most practical use. The demand for lowered costs on farm products and basic materials cannot be ignored.

With regard to highways and proportionate shares of expense in defraying the cost of their construction and maintenance, perhaps motor vehicles and related elements should pay more of the bill than they do at present, but they should not pay all of it. One idea is that they should bear the maintenance cost. What can and should be done varies with the locality.

When completed, highways belong to the public and not alone to those who use them. The case is different from that of the railroad, the roadbed and rights-of-way of which are corporately owned. The present conditions cannot be improved by undue taxation or regulation of motor vehicles. The capital cost of highways must be balanced with the saving in transportation cost to be had by operation of motor vehicles on them. Much more information is needed on costs of operation, including terminal expense. Adequate studies should be made of the effect of improved grades on highway vehicle efficiency. The whole aim of current highway research, in which the Society is cooperating, is economic regional conformity in the interest of the public. The public always eventually bears the expense of waste. Obviously, we cannot afford not to have a highway system that is commensurate in extent and quality with economic facts. The art and science of road-building have developed so that it is possible to determine the merit of subgrades, and unsatisfactory subgrade conditions can be cured, and should be cured in cases where it would not be less expensive to strengthen the road. There is definite information as to just what loads roads of different types will withstand. There is lack of knowledge as to what the maximum wheel-loads should be from the standpoint of economy. The problem is to fit the vehicle to the road, making the cost of operation a reasonable minimum. Transportation will be measured by its cost. The time is not far distant when there will be 20,000,000 motor vehicles on our roads. In the solution of the problems involved it is necessary that there be whole-hearted cooperation between the vehicle engineer and builder, the road builder, the State and Federal Government authorities and the public. It should be possible to state with considerable clearness what types of vehicle can be used most efficiently and economically in various kinds of hauling. The work to be done falls into two classes: (*a*) definite laboratory researches and (*b*) the securing of statistical data on engineering facts.

The Society of Automotive Engineers has pledged itself to participate aggressively and thoroughly in furthering the movement to this end, which has been definitely planned and launched after a conference of representatives, in addition to those of the Society, of the United States Bureau of Public Roads, the National Automobile Chamber of Commerce and the National Research Council. Let us not witness, in our day at least, the paralysis of transportation feared by President Harding.

THE 1923 ANNUAL MEETING

Will Be Found Described in This Issue of THE JOURNAL on p. 231

Economic Motor-Fuel Volatility

By R. E. Carlson[1]

Annual Meeting Paper *Illustrated with* Photographs and Charts

THE paper is a report covering an investigation made by the Bureau of Standards to secure data that can be used as a basis for estimating the effect of a change in gasoline volatility on the fuel-consumption of cars now in service throughout the United States. Actual tests began in August, 1922, to determine the effect of four fuels of different characteristics on the number of car-miles obtainable per gallon of fuel, as well as on crankcase-oil dilution.

Descriptions are given of the fuels used, the test-cars, the apparatus, the tests and the test methods, inclusive of the crankcase-oil dilution investigation, voluminous tabular data accompanying the text. Table 12 gives a summary of the results and these are discussed briefly. The program for a proposed similar investigation under low-temperature conditions is outlined.

THE continued growth of the automotive industry, with the consequent demand for fuel by the using public, has made the question of meeting this demand one of the most important economic considerations with which the Country is concerned. The question confronting the oil industry is how to meet the ever-increasing demand for fuel. Refinery methods have been the subject of much study, and continued improvement has increased the yield of gasoline from a given quantity of crude oil but, notwithstanding this progress on the part of the oil industry, there is still apparent the possibility of a wide gap between the quantity of gasoline required and the gasoline production from the available supply of crude oil.

A general discussion has been in progress, between the automotive and the oil industries, covering the demand on the part of the automotive industry for a fuel of certain characteristics and the ability of the oil industry to meet this demand.

The purpose for which this investigation was undertaken, by the Bureau of Standards in conjunction with the Society of Automotive Engineers, the American Petroleum Institute and the National Automobile Chamber of Commerce, was to secure data that could be used as a basis for estimating the effect of a change in gasoline volatility on the fuel-consumption of the cars now in service throughout the Country. If car-owners could, with equal satisfaction, use a less volatile fuel than the present grade and obtain approximately the same number of miles per gallon, the fuel-consumption would remain the same, while the gasoline production could be increased by at least 30 per cent, in case the heaviest of the four fuels tested in this investigation were used. This would represent a real economy to the average car-owner for the reason that this increased production would serve either to delay the tendency toward an increase in the price of gasoline, or at least to decrease its rate of rise. This is merely the operation of the law of supply and demand.

The cooperative feature of the investigation consisted of the furnishing of men and the loan of special equipment by the oil and the automotive industries through the American Petroleum Institute, the Society of Automotive Engineers and the National Automobile Chamber of Commerce, the Bureau assuming the responsibility for the actual carrying out of the work. Through this cooperation the oil and the automotive industries are at all times in close touch with the work, since their representatives are actually assisting in carrying it out in conjunction with the personnel of the Bureau. This cooperation familiarizes the representatives with Bureau facilities and procedure and, at the same time, the Bureau is benefited by a closer contact with the industry and the problems that confront it. The oil and the automotive industries have thus been brought more closely together in the working-out of a problem that affects, in a practical way, every user of gasoline-propelled equipment throughout the Country.

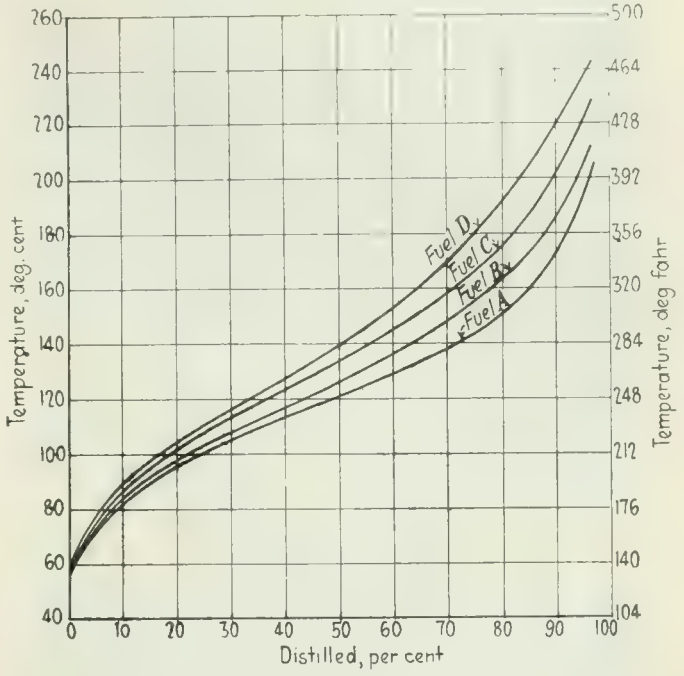


Fig. 1—Distillation Curves of the Four Fuels Used

The problems involved in this investigation have been discussed for the past year or two by those interested. As a result, a definite program of tests was formulated in the summer of 1922, and the Bureau was authorized to proceed. Actual tests were started in the first week of August. The program embraced a series of tests to determine the effect of four fuels of different characteristics on the number of miles per gallon obtainable as well as on crankcase-oil dilution. After a discussion of a report covering the work completed up to Oct. 1, 1922, the advisory committee decided that it would be desirable to continue the work under winter conditions. The continuation of the investigation under such conditions is now under way.

[1] Mechanical engineer, Bureau of Standards, City of Washington.

In this report, the results of the summer work will be presented, and the program for work under winter conditions discussed.

Investigation Under Summer Conditions

The summer work is covered in the following order:

(1) Fuels
(2) Cars
(3) Fuel-consumption tests
(4) Crankcase-oil dilution tests
(5) Results
(6) Discussion of results
(7) Conclusions

Fuels

Four grades of gasoline were selected and used throughout these tests. These were specially prepared by an Eastern refinery to meet the desired specifications. Their physical characteristics are shown in Table 1 and their distillation curves in Fig. 1. These grades of gasoline were designated by the letters, *A*, *B*, *C* and *D*. Grade *A*, which is the most volatile, is approximately the grade of gasoline that was generally available 4 or 5 years ago. Grade *B* corresponds approximately to the average motor-gasoline supplied at present. Grades *C* and *D* are less volatile.

TABLE 1—PHYSICAL CHARACTERISTICS OF THE FOUR TEST-FUELS

	Fuel							
	Grade *A*		Grade *B*		Grade *C*		Grade *D*	
	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.
Distillation, Initial	49.0	120	52.0	126	51.5	125	54.5	130
10 Per Cent	83.0	181	83.5	182	84.5	185	89.0	192
20 Per Cent	94.0	201	96.3	205	102.0	216	104.5	221
30 Per Cent	105.0	221	106.7	225	113.5	237	116.0	241
40 Per Cent	113.5	237	116.3	241	124.5	257	128.0	262
50 Per Cent	121.0	250	126.2	259	134.0	275	139.0	282
60 Per Cent	130.0	266	136.0	277	145.0	293	153.0	307
70 Per Cent	139.5	284	148.0	298	159.0	318	170.5	338
80 Per Cent	149.5	302	163.7	327	176.5	351	194.0	381
85 Per Cent	158.0	316	172.0	342	186.0	367	204.0	399
90 Per Cent	171.5	342	185.0	365	201.0	394	218.5	426
95 Per Cent	192.0	378	203.0	397	218.0	424	233.0	452
End, or High Point	206.5	403	214.0	417	229.5	446	244.5	472
Average Boiling-Point	121	250	125	257	135	275	142	288
Equilibrium Temperature[2]	151	304	163	325	176	349	192	378
Dew-Point, 12 to 1 Mixture[2]	11	52	31	88	47	117	67	153
Average Molecular Weight[2]	111.5		114.0		119.5		123.5	
Specific Gravity at 26 Deg.Cent.(78.5 Deg. Fahr)	0.727		0.733		0.736		0.740	
Index of Refinement, (26 deg. Cent.=78.5 Deg. Fahr.)	1.4110		1.4110		1.4150		1.4165	
Viscosity at 26 Deg. Cent. (78.5 Deg. Fahr.), centipoises	0.527		0.533		0.577		0.592	
Doctor Test	Sweet		Sweet		Sweet		Sweet	
Unsaturated Compounds, per cent	5.5		6.5		6.0		6.0	
Moisture Content	None		None		None		None	
Acidity	None		None		None		None	
Reaction Test	None		None		None		None	

[2]Wilson's Method.

Table 2 gives the possible production of these four fuels as estimated by several large refineries. On the basis of a 100 per cent production for Grade *B*, Grade *A* represents a decrease of approximately 12 per cent, Grade *C* an increase of approximately 13 per cent and Grade *D* an increase of approximately 30 per cent of gasoline from a given quantity of crude oil.

TABLE 2—ESTIMATED PRODUCTION OF FOUR TEST-FUELS, COMPARED WITH GRADE-*B* FUEL

Refiner	Fuel *A*	Fuel *B*	Fuel *C*	Fuel *D*
1	81	100	114	128
2	91	100	111	124
3	83	100	113	122
4	84	100	115	133
5	90	100	112	145
Average	86	100	113	130

Test Cars

Four makes of car were secured that were believed to represent approximately 75 per cent of the total number of cars now in use in the United States. The characteristics of these cars are given in Table 3. These cars are designated by the letters *W*, *X*, *Y* and *Z*. Considerable care was taken in the selection of each of these four cars, to obtain an average of each type so far as possible. The original equipment was left intact, and only sufficient overhauling and adjusting was done to insure having the cars remain in good condition during the test period.

TABLE 3—CHARACTERISTICS OF TEST-CARS USED

Car	*W*	*X*	*Y*	*Z*
Year	1920	1920	1920	1920
Number of Cylinders	6	4	4	4
Bore, in.	3⅜	3 1/16	3⅞	3¾
Stroke, in.	4½	4	4½	4
Piston Displacement, cu. in.	241.6	171.0	212.0	177.0
Power Rating[3], hp.	27.30	21.75	24.03	22.50
Wheelbase, in.	118	102	114	100
Weight, Including Equipment and Crew, lb.	3,760	2,450	3,210	2,335
Tires, in.	33x4	30x3½	32x3½	30x3 1/2
Gear-Ratio	4.000	3.670	4.166	3.630
Miles Run, Approximate	15,000	10,000	15,000	12,000

[3] Based on the National Chamber of Commerce formula.

Fuel-Consumption Tests

A comparison of the number of miles per gallon obtained with different fuels in a given car should be based on a measurement of the quantity of fuel consumed when the same number of foot-pounds of energy is delivered by the engine per mile under a specified schedule of speeds, either constant or changing, and when the operating conditions, such as the carbureter adjustment, the temperatures and the speed, are the same or are particularly adjusted to each fuel. If a car were towed around a definite course following a given schedule of speed-changes and the results of a measurement of the pounds pull on a drawbar dynamometer at each instant plotted against distance traveled, the area under the curve would represent the number of foot-pounds of work done in towing the car over the course. If the run were repeated and the wind, the road surface, the lubricant temperature, the car weight and the tire pressure remained the same, the same curve would be obtained. If the car were driven by its engine through the same series of operations, the energy output of the engine would be identical with that previously registered by the dynamometer. If several runs were made within a short time, the changes in the wind, the lubricant temperature and the tire pressure would not change sufficiently to affect the number of foot-pounds of energy output materially. If two suc-

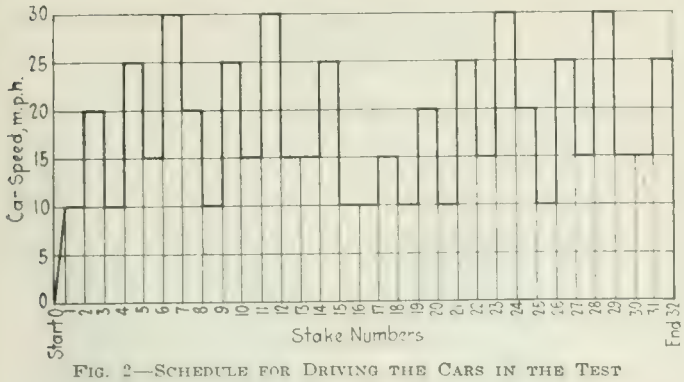


FIG. 2—SCHEDULE FOR DRIVING THE CARS IN THE TEST

cessive runs were made following identically the same schedule, but when two different fuels were supplied to the engine, the ratio of the quantities of fuel used in the two runs would represent the ratio of the number of miles per gallon to be expected from the two fuels when used in that car under the conditions of driving obtaining in the run.

In these tests, three successive runs were made on one fuel, before changing to a second, with which three more successive runs, were made. By means of the sets of three successive runs a constant check was obtained on the constancy of the energy output. To increase the reliability of the results, at least two such independent comparisons were made. The fuels were compared with each other by comparing, independently, Grades *A*, *C* and *D* with Grade *B*, or the reference fuel. It was found that the set of six runs used in each comparison could be made in from 2 to 3 hr, and no material variation in energy output was anticipated in this time.

The driving schedule used in these tests is shown schematically in Fig. 2. The maximum speed was limited by traffic regulations but the range of speed, acceleration and deceleration was estimated to be that usually encountered in ordinary driving. All accelerations were made with wide-open throttle, and decelerations with fully closed throttle and without the use of brakes. These two arbitrary conditions of driving operation were imposed to obtain more reproducible handling of the throttle and to eliminate the uncertainty of varying use of the brakes.

TABLE 4—SUMMER TESTS, CAR *W*; SAME CARBURETER SETTING FOR ALL FUELS

Grade of Fuel	Carbureter Setting	Total Time, Sec.	Total Fuel Used CC.	Average Time, Sec.	Average Fuel, CC.	Fuel-Consumption CC. per Sec.	Gal. per Hr.	Miles per Gal.	Ton-Miles per Gal.
B	4.4	735.4 738.4 746.7	643.9 642.8 633.2	740	640	0.865	0.822	19.1	35.8
C	4.4	746.6 740.4 735.8	645.2 650.9 646.5	741	648	0.874	0.831	18.8	35.4
B	4.4	731.0 739.7 740.6	644.3 641.7 642.1	737	643	0.873	0.830	19.0	35.7
C	4.4	738.4 759.0 755.0	640.4 634.3 634.1	751	636	0.848	0.806	19.1	35.9
B	4.4	722.3 724.2 717.2	645.4 659.5 639.0	721	648	0.899	0.854	18.8	35.4
A	4.4	719.8 724.3 725.1	664.8 651.7 651.9	723	656	0.908	0.864	18.6	34.9
B	4.4	719.3 734.7 732.3	649.7 640.7 643.4	729	645	0.884	0.841	18.9	35.5
A	4.4	734.6 728.6 647.7*a*	647.3 639.5 567.1	732*b*	643*b*	0.878*c*	0.835*c*	19.1*c*	35.9*c*
B	4.4	725.5 726.6 734.7	645.7 655.1 650.3	729	653	0.896	0.852	18.7	35.1
D	4.4	735.1 736.5 737.4	646.3 625.6 641.6	736	638	0.866	0.823	19.1	35.9
B	4.4	742.3 739.0 743.1	650.3 642.6 632.7	742	642	0.866	0.823	19.0	35.7
D	4.4	749.2 739.7 746.8	645.6 638.1 621.6	745	635	0.854	0.812	19.2	36.1

General Averages

B	4.4	.....	.....	739	641	0.869	0.826	19.0	35.7
C	4.4	.....	.....	745	642	0.861	0.818	19.0	35.7
B	4.4	.....	.....	725	646	0.892	0.848	18.9	35.4
A	4.4	.....	.....	727	650	0.893	0.850	18.8	35.4
B	4.4	.....	.....	735	648	0.881	0.838	18.9	35.4
D	4.4	.....	.....	741	637	0.860	0.818	19.1	36.0

*a*Watch stopped just after passing stake No. 29.
*b*Average of two runs.
*c*Average of three runs.

TABLE 5—SUMMER TESTS, CAR *W*; CHANGED CARBURETER SETTING FOR EACH FUEL

Grade of Fuel	Carbureter Setting	Total Time, Sec.	Total Fuel Used, CC.	Average Time, Sec.	Average Fuel, CC.	Fuel-Consumption CC. per Sec.	Gal. per Hr.	Miles per Gal.	Ton-Miles per Gal.
B	4.40	724.7 725.1 730.7	648.4 634.3 608.6	727	630	0.868	0.826	19.3	36.3
A	5.00	726.9 717.0 724.6	599.3 595.6 594 1	723	596	0.825	0.785	20.4	38.4
B	4.40	717.2 724.8 726.4	624.9 624.4 624.1	723	625	0.866	0.824	19.5	36.7
A	5.00	741.0 735.1 724.8	591.7 592.4 592.7	734	592	0.808	0.768	20.6	38.7
B	4.40	713.0 711.5 717.0	663.0 653.5 657.1	714	658	0.922	0.877	18.5	34.8
D	3.75	713.0 716.2 710.5	674.9 676.4 668.3	713	673	0.944	0.898	18.1	34.1
B	4.40	710.0 713.4 719.3	632.5 623.5 616.2	714	624	0.874	0.831	19.5	36.7
D	3.75	721.2 717.0 715.0	664.9 657.9 670.0	718	664	0.926	0.881	18.4	34.5
B	4.40	723.5 717.0 717.6	634.4 639.4 640.0	719	638	0.886	0.884	19.1	35.8
C	4.00	723.4 715.2 718.0	679.2 670 8 662.6	719	671	0.933	0.887	18.1	34.1
B	4.40	719.1 712.8 719.8	648.1 638.2 625.5	717	637	0.888	0.845	19.1	35.8
C	4.00	727.2 726.0 719.8	654.1 661.6 657.8	724	658	0.906	0.862	18.5	34.8

General Averages

B	4.40	.....	.....	725	627	0.867	0.823	19.4	36.5
1	5.00	.....	.....	728	596	0.817	0.776	20.5	38.5
B	4.40	.....	.....	714	643	0.898	0.854	19.0	35.7
D	3.75	.....	.....	716	670	0.935	0.890	18.2	34.3
B	4.40	.....	.....	718	638	0.887	0.845	19.1	35.8
C	4.00	.....	.....	722	664	0.920	0.875	18.3	34.5

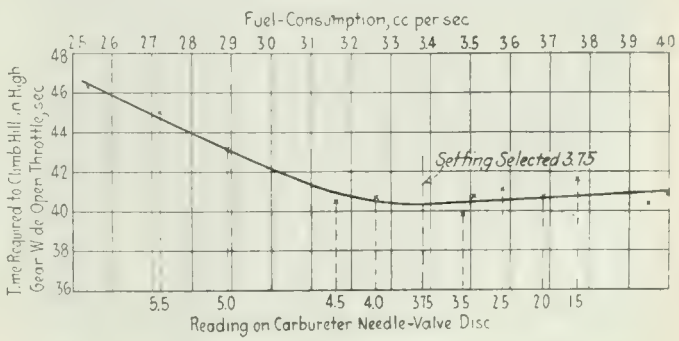

Fuel-Consumption, cc per sec
Time Required to Climb Hill on High Gear Wide Open Throttle, sec
Setting Selected 3.75
Reading on Carbureter Needle-Valve Disc

FIG. 3—CHART SHOWING HOW THE CARBURETER SETTING FOR MAXIMUM POWER WAS DETERMINED

The driving schedule used in these tests is shown schematically in Fig. 2. The maximum speed was limited by traffic regulations but the range of speed, acceleration and deceleration was estimated to be that usually encountered in ordinary driving. All accelerations were made with wide-open throttle, and decelerations with fully closed throttle and without the use of brakes. These two arbitrary conditions of driving operation were imposed to obtain more reproducible handling of the throttle and to eliminate the uncertainty of varying use of the brakes.

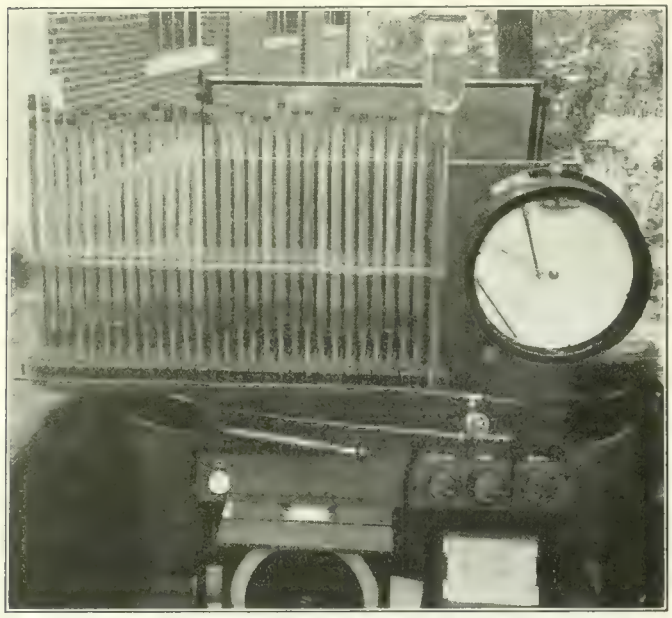


FIG. 4—APPARATUS EMPLOYED TO MEASURE THE FUEL, THE CAR SPEED, THE MANIFOLD DEPRESSION AND THE TEMPERATURE

The test-course selected is located in Potomac Park, City of Washington, and is known locally as the Speedway. The road is of asphalt, is in good condition and is practically flat. The course is 3.2 miles long. For the purpose of this work, it was divided into 32 sections,

TABLE 6—SUMMER TESTS, CAR *X*; FIXED-JET CARBURETER-SETTING

Grade of Fuel	Carbureter Setting	Total Time, Sec.	Total Fuel Used, CC.	Average Time, Sec.	Average Fuel, CC.	Fuel-Consumption: CC. per Sec.	Gal. per Hr.	Miles per Gal.	Ton-Miles per Gal.
B	Fixed Jet	710.4	526.8	713	527	0.739	0.703	23.1	29.2
		711.4	523.8						
		716.4	529.4						
C		705.4	522.4	705	532	0.755	0.718	22.9	28.9
		709.8	536.6						
		699.0	537.8						
B		703.4	545.5	703	547	0.777	0.739	22.3	28.1
		706.9	550.4						
		698.6	543 7						
C		689 0	543.5	688	543	0.789	0.751	22.4	28.3
		676.0	546.3						
		699.6	540.5						
B		689.8	504.2	687	500	0.729	0.694	24.4	30.7
		687.0	497.8						
		683.2	498.9						
A		689.2	513 9	688	510	0.743	0.707	23.9	30.1
		693.5	513.9						
		680.0	503.3						
B		682.8	496 5	681	497	0.729	0.694	24.5	30.9
		685.1	498.5						
		676.4	495.7						
A		687.3	509.2	682	506	0.741	0.705	24.1	30.4
		682.0	507.2						
		677.1	500.3						
B		715.0	514.1	719	518	0.721	0.686	23.5	29.6
		727.6	518.0						
		712.8	522.2						
D		715.0	495.5	714	504	0.706	0.671	24.2	30.5
		713.0	505 1						
		712.8	511.0						
B		712.5	520.7	711	519	0.730	0.694	23.5	29.6
		709.0	514.3						
		711.4	522.4						
D		707.5	501.6	710	509	0.717	0.681	24.0	30.2
		712.8	512.5						
		710.9	511.9						
General Averages									
B	Fixed Jet	.....	.....	708	537	0.758	0.721	22.7	28.7
C		.....	.....	696	538	0.772	0.735	22.7	28.6
B		.....	.....	684	499	0.729	0.694	24 4	30 8
A		.....	.....	685	508	0.742	0.706	24.0	30.3
B		.....	.....	715	519	0.726	0.690	23.5	29.6
D		.....	.....	712	506	0.711	0.676	24.1	30.3

TABLE 7—SUMMER TESTS, CAR *Y*; SAME CARBURETER SETTING FOR ALL FUELS

Grade of Fuel	Carbureter Setting	Total Time, Sec.	Total Fuel Used, CC.	Average Time, Sec.	Average Fuel, CC.	Fuel-Consumption: CC. per Sec.	Gal. per Hr.	Miles per Gal.	Ton-Miles per Gal.
B	55	677.3	655.6	675	646	0.956	0.909	18.9	30.3
		671.8	650.0						
		677.2	631.9						
A	55	672.3	661.1	675	670	0.988	0.939	18.3	29.3
		675.0	665.7						
		677.3	673.9						
B	55	667.3	637.2	670	643	0.960	0.913	18.9	30.4
		667.9	649 8						
		664.6	641.6						
A	55	667.0	669.5	666	670	1.005	0.956	18.2	29.2
		666.8	665 9						
		665.2	673.7						
B	55	680 4	652 6	674	650	0.974	0.926	18 8	30 1
		667.8	646.7						
		590 4[d]	587.6						
C	55	676.6	639.9	671	633	0.944	0.897	19.3	31 0
		670.6	636.1						
		665.7	622.2						
B	55	682.0	645.9	673	644	0.958	0.911	18.9	30.4
		668.6	639.5						
		669.4	647.3						
C	55	674.4	619 8	672	614	0.914	0.869	19.8	31.9
		672.9	611.9						
		668.6	610.2						
B	55	667.0	652.6	664	652	0.982	0.934	18.7	30.1
		662.8	659.1						
		661.6	642.9						
D	55	657.4	622.6	661	611	0.925	0 880	19.9	32.0
		661.6	609.8						
		663.3	601.4						
B	55	660.9	648 3	664	652	0.983	0.935	18.7	30.0
		669.8	660.7						
		660.0	647.0						
D	55	670.1	630.9	668	619	0.926	0 880	19.7	31.6
		664 7	611 1						
		669 9	613 7						
General Averages									
B	55	.....	.....	673	644	0.958	0.911	18.9	30.3
A	55	.....	....	671	670	0.997	0.948	18.2	29.3
B	55	.....	. . .	674	647	0.966	0.916	18.8	30.2
C	55	.....	. .	672	623	0.928	0 883	19.6	31.4
B	55	.....	. . .	664	652	0.983	0.935	18.7	30.0
D	55	.....	....	665	615	0.925	0.880	19.8	31.8

[d] Throttle valve-rod jumped out of throttle valve-lever just after passing stake No. 29.

FIG. 5—THE FUEL-SUPPLY TANKS AND THE DRIVER'S SPEEDOMETER

TABLE 8—SUMMER TESTS, CAR *Y*; CHANGED CARBURETER SETTING FOR EACH FUEL

Grade of Fuel	Carbureter Setting	Total Time, Sec.	Total Fuel Used, CC.	Average Time, Sec.	Average Fuel, CC.	Fuel-Consumption			
						CC. per Sec.	Gal. per Hr.	Miles per Gal.	Ton-Miles per Gal.
B	55	671.1 662.6 661.4	665.7 659.2 658.4	665	661	0.994	0.946	18.4	29.6
A	85	665.8 665.9 664.8	621.9 614.2 604.6	665	647	0.972	0.924	18.8	30.3
B	55	669.3 674.3 670.6	663.4 662.5 671.2	671	666	0.991	0.943	18.3	29.4
A	85	678.5 678.3 681.0	646.1 637.4 644.4	679	643	0.946	0.900	18.9	30.5
B	55	660.3 668.3 660.5	648.4 649.6 650.6	663	650	0.980	0.932	18.8	30.1
C	45	658.7 656.6 665.6	641.1 650.0 627.6	660	636	0.964	0.917	19.1	30.8
B	55	667.8 660.6 666.3	654.9 658.2 647.3	665	654	0.983	0.935	18.6	29.9
C	45	666.4 666.0 659.6	636.6 654.5 630.1	663	640	0.966	0.919	19.0	30.6
B	55	671.9 670.1 668.6	626.3 621.1 625.8	670	624	0.932	0.887	19.5	31.3
D	30	663.0 670.7 669.8	624.9 629.2 639.8	668	635	0.951	0.905	19.2	30.8
B	55	666.3 665.7 659.7	647.4 634.0 629.0	664	637	0.960	0.913	19.1	30.7
D	30	662.7 662.7 670.0	642.1 631.1 629.8	665	634	0.954	0.908	19.2	30.8
General Averages									
B	55	.....	.....	668	663	0.992	0.944	18.4	29.5
A	85	.. ..	....	672	645	0.964	0.912	18.9	30.4
B	55	..	...	664	651	0.981	0.933	18.7	30.0
C	45	...		662	638	0.965	0.918	19.1	30.7
B	55	..	..	667	631	0.946	0.900	19 3	31.5
D	30			667	634	0.953	0 906	19 2	30.8

each section being 0.1 mile in length and marked by a sign-post on which driving instructions were indicated. The same operations were repeated on the two sides of the course, which are approximately parallel, so as to minimize the effect of wind on the accuracy of the results.

In the case of all the cars, except car *X*, which has a fixed-jet type of carbureter, two series of comparisons were made. One series was made with all the fuels, using the optimum adjustment for Grade-*B* fuel; the second series was made with the respective optimum settings for the fuels. The carbureter setting for each fuel was obtained by driving in high-gear up a given hill, and measuring the time required to make the ascent, as well as the amount of gasoline consumed. These runs were made over the range from a very lean to a very rich setting, and for the four fuels used. From these results, the gasoline consumption was plotted against the time of ascent and, from the curve for each fuel, the leanest setting giving the minimum time of ascent was selected, as illustrated by Fig. 3 for car *W*. In the case of two of the cars the carbureter settings were made by factory engineers; these agreed exactly with the settings obtained from the hill-test. An analysis of the exhaust-gas obtained from this setting indicated a mixture-ratio of approximately 12 lb. of air per lb. of fuel. The use of a materially leaner carbureter setting gave unsatisfactory results during the accelerations made on the Speedway test-course, which averaged from 1½ to 2 m.p.h. per sec.

The apparatus used in these tests is shown in Figs. 4, 5 and 6. The fuel-measuring system shown in Fig. 4 consisted of 32 burettes, each of 50-cc. capacity, and having the zero at the top. Each burette was provided at the bottom with a rubber tube and cut-off cock of such design that a single movement of the actuating lever closed one burette and opened the adjoining one. Gasoline was drawn from a given burette for each section of the course, this being opened at the beginning of the section when the stake was passed and closed at the end when the next stake was passed. Each burette therefore indicated the fuel consumed while passing over a given section of the course, under prescribed driving conditions such as acceleration, constant speed or deceleration. When the car had traversed the entire course, the burette readings were recorded, and their sum gave the total fuel-consumption for the circuit of the course.

Two separate fuel-tanks were used one to hold the Grade-*B* or reference fuel, and the other the fuel under test. These tanks are shown in Fig. 5. An air-pump was used to force the fuel from these tanks up to the glass reservoir shown at the right in Fig. 4. Before starting each run, the burettes were filled up to their zero-marks from this reservoir. When it was desired to change fuel, the valve in this line was opened and permitted all of the fuel in the burettes and the reservoir to be drained back into the proper tank. The line from the burettes to the carbureter was emptied of fuel by running the engine. The end of the test-course is some distance from the start, and changing fuels at the end insured running on new fuel by the time the car had reached the starting-point.

A graphic record of car-speed changes during the progress of a run was obtained by connecting a pen movement to a Van Sicklen chronometric tachometer, and mounting them on the recording vacuum gage used to record the manifold depression. Fig. 6 shows the ar-

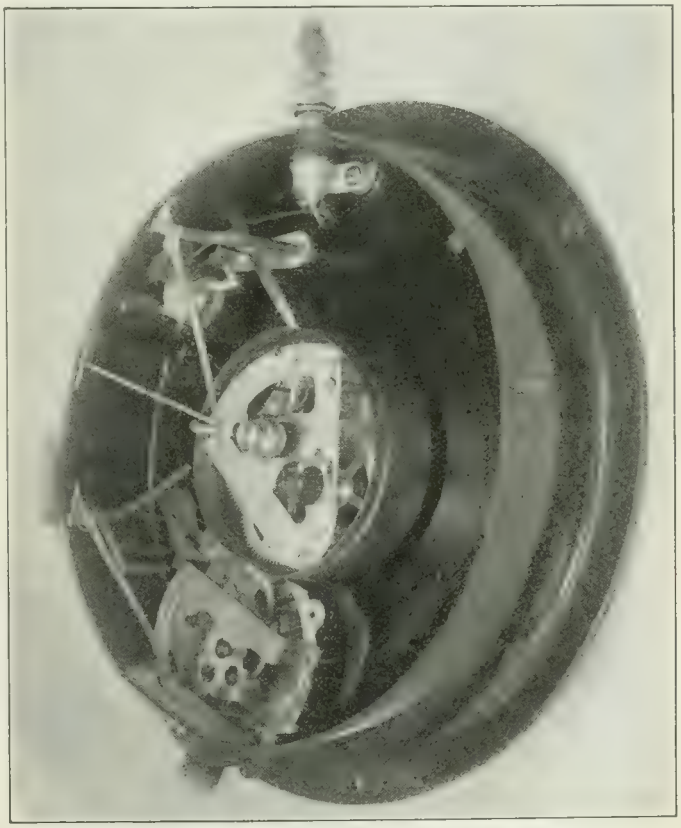


FIG. 6—ARRANGEMENT OF THE CAR-SPEED AND MANIFOLD-DEPRESSION RECORDER

rangement of the instrument used to give the combined record of car speed and manifold depression.

The temperatures of the outlet water and of the lubricant in the crankcase and the differential were determined by distance-type indicating-thermometers. The air temperatures were indicated by a mercurial thermometer.

Both the time required to pass over each section of the course and the time of a complete circuit were obtained by split-second stop-watches of the double-sweep type. These stop-watches were checked a number of times by the time section of the Bureau to determine their accuracy.

Fig. 7 shows a typical record-sheet. It will be noted that the temperatures were recorded at the beginning and the end of each run. The sheet also gives the tire pressures at the start and at the end of each test. The relative humidity and the barometric pressures as recorded were obtained from the United States Weather Bureau.

A combined manifold-depression and car-speed record, like that shown by Fig. 8, was obtained for each run. The record of the car-speed change is shown by the graph

Cooperative Fuel Research
COMPUTATION SHEET
DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS

TEST NO 4 Car "Y" Tach No. 4 DATE 8-17-22
Time Fuel D Carb. Sett .55 Burette NO.

	A	B	C	D	E	F	G	H	I	J	K
								TEMPERATURE			
	Run Numbers	Run Time	No. 1 oo used	Run Time	No. 3 oo used	Run Time	No. 3 oo used	Water	Diff	Crank Case	Air
	St	8.7	4.4	9.7	6.6	9.5	9.4		Run No. 1		
	1	44.7	17.2	44.7	15.6	44.5	16.1	66	26	31.5	19.5
	2	1-04.5	26.0	1-04.5	24.8	1-04.3	24.6	65	32	39	20.5
	3	1-32.8	11.8	1-31.5	9.6	1-31.0	11.9		Run No. 2		
	4	1-50.0	29.6	1-49.1	30.7	1-48.3	30.4	62	30.5	37	20.3
	5	2-09.4	10.7	2-09.0	8.8	2-07.5	10.2	67	34.5	40	21.2
	6	2-23.6	38.8	2-22.8	37.0	2-21.7	37.9		Run No. 3		
	7	2-38.0	5.6	2-38.5	8.8	2-36.5	6.2	62	31	38.5	20.9
	8	3-04.9	10.6	3-05.3	11.6	3-02.6	10.4	66	35	40	21.6
	9	3-22.1	33.9	3-22.3	32.6	3-19.6	31.6	Place of Test			
	10	3-41.2	7.1	3-40.8	8.2	3-39.0	8.0		Driver	G A B	
11-12		3-55.3	37.7	3-55.3	37.9	3-53.5	38.1	Crew	Obser.	H M R	
	13	4-34.2	19.8	4-34.7	22.0	4-33.6	20.8		Record.	E W E	
14-15		4-49.4	27.2	4-50.3	26.5	4-49.2	27.1	Car Weight		3200#	
	16	5-43.5	25.1	5-45.5	23.9	5-44.0	23.6		Start	65#	Type Tires
	17	6-08.1	20.6	6-10.4	20.0	6-07.8	19.4	Tire Press.	Middle	—	U.S. ROYAL CORD
	18	6-40.8	15.8	6-42.2	14.9	6-40.4	15.3		Stop	68#	
	19	7-00.5	24.3	7-01.8	24.9	6-59.7	25.0	Barom.	Start	762.5	
	20	7-28.7	13.1	7-28.2	12.0	7-28.0	11.8		Stop	761.0	
	21	7-45.8	32.0	7-45.5	31.4	7-45.2	36.7	Oil Used		VEEDOL	Med
	22	8-05.1	8.8	8-05.3	9.7	8-05.2	9.4	Rel. Humidity		61	
	23	8-19.6	43.6	8-19.6	42.5	8-19.7	39.6	Wind	Direct.	SW	
	24	8-34.7	7.6	8-35.1	8.6	8-35.0	7.8		Veloc.	5.14	
	25	9-02.1	12.1	9-01.6	11.6	9-01.8	10.7	Weath.	AM	FAIR	
	26	9-19.2	31.2	9-19.3	32.4	9-18.9	34.0		PM	FAIR	
	27	9-39.5	9.0	9-38.8	9.5	9-38.2	7.8	Ave Time		670.2	
28-29		9-54.5	39.5	9-53.6	41.5	9-52.8	40.1	Ave cc		624.4	
	30	10-35.7	22.9	10-34.0	19.5	10-33.8	21.9	Ave cc/sec		.932	
	31	10-51.5	29.0	10-50.2	28.7	10-49.5	30.2	Gal/Hour		.886	
	32	11-11.9	11.3	11-10.1	9.3	11-08.6	9.8	Mi/Gal.		19.5	
Totals		671.9	626.3	670.1	621.1	668.6	625.8	T Mi/Gal		31.3	
								General Remarks over.			

Form 869 11 7948

FIG. 7—A TYPICAL SHEET OF ONE OF THE TESTS

on which is marked the car speed. A template was made with which the car-speed record obtained from each run was compared to see how closely the car had followed the predetermined running-schedule. By this comparison, bad runs were easily detected and thrown out. The record of manifold depression gave an indication of the throttle operation by the car driver.

CRANKCASE-OIL DILUTION TESTS

To obtain an indication of the effect of these four fuels on crankcase-oil dilution, two cars, namely *Y* and *Z*,

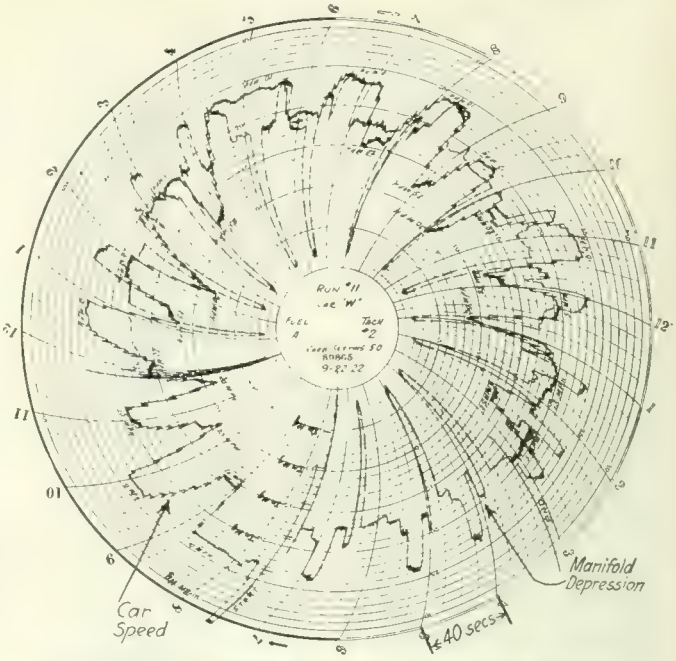


FIG. 8—CHART OBTAINED FROM THE CAR-SPEED AND MANIFOLD-DEPRESSION RECORDER

were driven between the City of Washington and Frederick, Md. This road is in fairly good condition and includes a relatively large number of hills. An average

TABLE 9—SUMMER TESTS, CAR *Z*; CARBURETER SETTING SAME FOR ALL FUELS

Grade of Fuel	Carbureter Setting	Total Time, Sec.	Total Fuel Used CC.	Average Time, Sec.	Average Fuel, CC.	Fuel-Consumption CC. per Sec.	Gal. per Hr.	Miles per Gal.	Ton-Miles per Gal.
B	7.0	685.4	553.6	684	555	0.811	0.772	22.0	25.6
		681.0	558.3						
		685.8	552.8						
A	7.0	675.6	571.7	673	563	0.836	0.795	21.6	25.3
		678.0	561.8						
		666.5	555.5						
B	7.0	689.5	563.7	682	563	0.824	0.784	21.7	25.3
		681.0	565.0						
		676.4	559.2						
A	7.0	681.0	581.4	679	581	0.855	0.813	21.0	24.5
		678.1	577.5						
		678.4	584.3						
B	7.0	680.5	564.0	679	557	0.821	0.781	21.9	25.5
		680.0	555.8						
		677.0	522.0						
C	7.0	679.6	538.4	678	543	0.802	0.763	22.4	26.2
		673.6	539.6						
		679.3	551.4						
B	7.0	671.0	556.8	673	557	0.828	0.788	21.9	25.5
		675.5	554.6						
		673.8	560.6						
C	7.0	681.2	559.0	677	543	0.802	0.763	22.4	26.2
		673.5	555.0						
		675.3	514.8						
B	7.0	673.7	555.9	671	557	0.830	0.789	21.9	22.5
		673.4	557.6						
		667.8	558.5						
D	7.0	667.0	537.2	668	540	0.808	0.768	22.6	26.4
		666.2	545.4						
		669.7	536.5						
B	7.0	667.4	548.6	662	544	0.823	0.782	22.4	26.1
		659.2	542.7						
		658.8	541.1						
D	7.0	670.8	542.0	672	541	0.805	0.766	22.5	26.3
		677.7	540.7						
		667.3	540.0						
General Averages									
B	7.0	.....	.....	683	559	0.818	0.778	21.8	25.5
A	7.0	.....	.....	676	572	0.846	0.804	20.3	24.9
B	7.0	.....	.....	676	557	0.825	0.784	21.9	25.5
C	7.0	.....	.....	677	543	0.802	0.763	22.4	26.2
B	7.0	.....	.....	667	551	0.827	0.786	22.1	25.8
D	7.0	.....	.....	670	540	0.808	0.767	22.6	26.3

TABLE 10—SUMMER TESTS, CAR *Z*; CHANGED CARBURETER SETTING FOR EACH FUEL

Grade of Fuel	Carbureter Setting	Total Time, Sec.	Total Fuel Used, CC.	Average Time, Sec.	Average Fuel, CC.	Fuel-Consumption: CC. per Sec.	Gal. per Hr.	Miles per Gal.	Ton-Miles per Gal.
		674.3	532.2						
B	7.0	672.2	525.2	670	531	0.793	0.754	23.0	26.8
		666.3	534.9						
		668.6	538.8						
A	7.1	667.9	538.5	668	531	0.798	0.759	22.9	26.7
		666.2	536.6						
		671.4	543.1						
B	7.0	667.2	545.2	669	545	0.815	0.775	22.4	26.1
		667.9	547.2						
		670.7	527.8						
A	7.1	670.0	533.8	671	531	0.792	0.753	22.9	26.7
		672.2	531.7						
		673.4	540.6						
B	7.0	665.3	542.7	669	539	0.808	0.768	22.6	26.4
		664.8	535.5						
		669.8	550.9						
C	6.4	670.0	546.5	670	549	0.821	0.781	22.2	25.9
		667.0	549.0						
		667.3	539.0						
B	7.0	664.8	536.3	666	533	0.801	0.762	22.9	26.7
		664.5	523.8						
		661.5	535.4						
C	6.4	669.4	538.5	666	540	0.812	0.773	22.6	26.3
		665.8	547.3						
		664.0	537.1						
B	7.0	672.7	537.0	668	530	0.798	0.759	22.7	26.5
		667.4	525.4						
		666.2	534.8						
D	6.3	663.8	548.8	663	547	0.743	0.707	22.3	26.0
		658.5	557.2						
		663.8	534.8						
B	7.0	662.2	526.7	662	533	0.823	0.783	22.9	26.8
		658.5	536.3						
		661.3	550.2						
D	6.3	664.6	550.8	664	552	0.831	0.698	22.2	25.9
		665.5	553.5						
General Averages									
B	7.0	.....	.....	670	538	0.804	0.765	22.7	26.5
A	7.1	.....	.....	669	531	0.795	0.756	22.9	26.7
B	7.0	.....	.....	667	536	0.805	0.765	22.7	26.6
C	6.4	.....	.....	666	545	0.817	0.777	22.4	26.1
B	7.0	.....	.....	665	533	0.810	0.770	22.8	26.6
D	6.3	.....	.....	663	549	0.790	0.702	22.3	26.0

speed of 25 m.p.h. was maintained; this speed was checked by having the time of arrival and departure recorded at intermediate points between Washington and Frederick.

Two round-trips, representing a total of 200 miles, were made for each fuel. Before the start of the run on each fuel, the crankcase was drained, new oil put in and the engine run for from 5 to 10 min. This oil was then drained out and the crankcase filled with new oil. No oil was added during the 200-mile run. After each 50

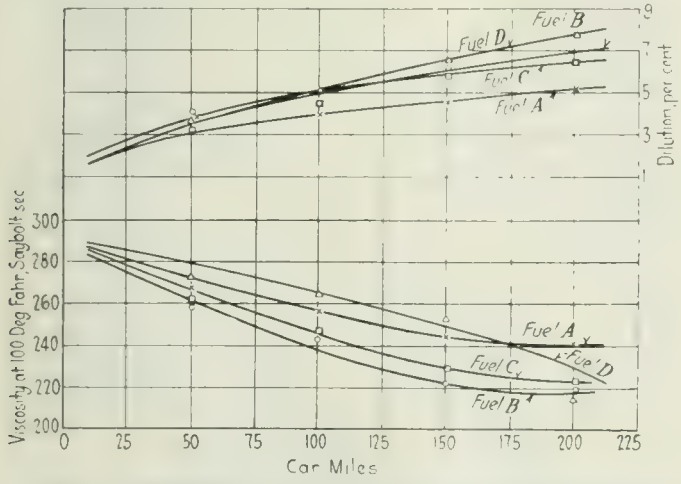


FIG. 9—CURVES SHOWING THE CHANGE IN THE CRANKCASE-OIL DILUTION AND THE VISCOSITY IN THE SUMMER ROAD TESTS

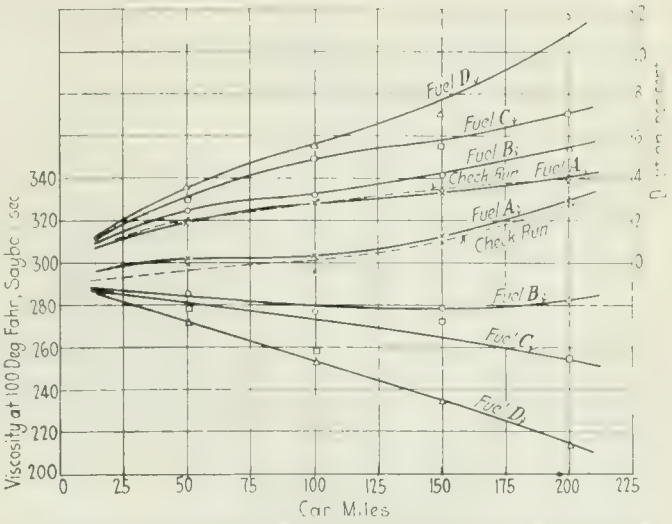


FIG. 10—A SIMILAR SET OF CURVES OBTAINED FROM A DIFFERENT CAR

miles, 8-oz. samples were taken and these were tested for the percentage of dilution and change in the viscosity. The figures given for the percentage of dilution were obtained by subtracting the percentage distilled off from the unused oil up to 300 deg. cent., (572 deg. fahr.) from the percentage distilled off from the used oil up to the same temperature.

DISCUSSION OF RESULTS

The results obtained from the summer work on the Speedway course are given in Tables 4 to 10 inclusive. It will be noted from the data that the fuel-consumptions obtained from three successive runs on any one fuel generally agree within 3 per cent, and it is estimated that the general averages are reliable within 2 per cent.

The results of the road tests for dilution are shown in Table 11 and Figs. 9 and 10. The results obtained from the road tests for crankcase-oil dilution are of interest as indicating a probable increase in dilution with the use

TABLE 11—SUMMER ROAD-TESTS FOR CRANKCASE-OIL DILUTION

Miles Run	Car *Y* 50	100	150	200	Car *Z* 50	100	150	200
Grade *A* Fuel								
Viscosity[3]	265	256	244	242	303	311	312	331
Dilution, per cent	2.8	3.0	3.5	4.1	2.0	3.0	3.4	4.2
Grade *A* Fuel								
Viscosity[3]	....	....	....	....	301	295	312	328
Dilution, per cent.	....	....	....	....	2.0	3.0	3.3	3.8
Grade *B* Fuel								
Viscosity[3]	258	244	238*e*	236	.....	.....	.....	.....
Dilution, per cent	3.0	4.0	4.3	5.3	.....	.....	.....	.....
Grade *B* Fuel								
Viscosity[3]	259	247	222	220	286	277	279	282
Dilution, per cent	2.8	3.3	5.5	5.5	2.6	3.1	4.2	5.4
Grade *C* Fuel								
Viscosity[3]	261	248	231	222	278	256	273	255
Dilution, per cent	2.2	3.5	5.0	5.5	3.0	5.0	5.5	7.0
Grade *D* Fuel								
Viscosity[3]	272	265	254	215	272	255	235	213
Dilution, per cent	2.8	4.0	5.5	6.7	3.5	5.5	7.0	12.0

NEW OIL USED; VEEDOL MEDIUM

Specific Gravity	0.899
Baume, deg	25.7
Flash Point, deg. fahr	420
Fire Test, deg. fahr	480
Pour Test, deg. fahr	25
Viscosity: At 100 Deg. Fahr., Saybolt sec.	290
Viscosity: At 130 Deg. Fahr., Saybolt sec.	143
Viscosity: At 212 Deg. Fahr., Saybolt sec.	51
Boiling Point, deg. cent	305
Boiling Point, deg. fahr	581

[3]At 100 Deg. Fahr.
*e*Quart of oil added by mistake.

TABLE 12—PERCENTAGE OF CAR-MILES PER GALLON OF FUEL, REFERRED TO GRADE-*B* FUEL

Car	Carbureter Set for Grade *B* Fuel				Carbureter Set for Each Fuel			
	Fuels				Fuels			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*
W	100	100	100	101	106	100	96	96
X	98	100	100	103	....	....	....	....
Y	96	100	104	106	103	100	102	99
Z	98	100	102	102	101	100	99	98

of the less volatile fuels. It was realized that under summer weather conditions the dilutions obtainable would be relatively small; for this reason, the tests were not made more comprehensive.

The results are summarized in Table 12, on the basis of the number of miles per gallon.

This table gives the miles per gallon of each fuel, expressed as the percentage of that obtained with the Grade-*B*, or reference, fuel. The greatest difference in miles per gallon is in the case of car *W* when the carbureter was adjusted for each fuel. In this instance the number of miles per gallon with Grade-*A* fuel was 10 per cent *greater* than with the Grade-*D* fuel. However, it will be noted that with the same adjustment for all fuels, the number of miles per gallon on Grade-*A* fuel was 1 per cent *less* than on Grade-*D* fuel. This fact emphasizes the sensitivity of the results to small changes in the carbureter adjustment and, hence, the consequent difficulty of making such adjustments. It seems likely therefore that this 10 per cent difference is an effect due to improper carbureter adjustment, rather than to an inherent difference in the fuels themselves. If, however, this was not the case and a difference of this magnitude existed, when it is considered that the relative production from a barrel of crude would be 44 per cent greater with Grade-*D* fuel than with Grade-*A* fuel, there is no question that, from the standpoint of the number of miles per barrel of crude oil, the economic advantage would lie with the Grade-*D* fuel.

An examination of the results obtained with the other cars when the carbureters were adjusted for each fuel will show that the maximum difference between the fuels is about 4 per cent. In this group a car is included that represents probably 50 per cent of the total number now in use.

It is concluded from these tests that, on the basis of the number of miles per barrel of crude oil, the advantage among the fuels tested lies with the fuel of lowest volatility when used under summer conditions. Whether the use of this fuel represents a real economic gain depends on whether its use will result in disadvantages of sufficient magnitude to offset the gain in the number of miles per gallon of crude oil.

Investigation Under Low-Temperature Conditions

After considering the results of the summer tests, the advisory committee, representing the Society of Automotive Engineers, the American Petroleum Institute and the National Automobile Chamber of Commerce, decided to continue this work under cold-weather conditions. It was the consensus of opinion of the members that if there were any marked differences between the four test-fuels in the number of miles per gallon, the ease of starting and the crankcase-oil dilution, these differences might be more evident when testing the fuels under winter conditions. In addition to obtaining purely comparative data, a broadening of the scope of the program was authorized to permit making a study of the conditions that would be of major influence on the questions under investigation; namely, economy, ease of starting, acceleration and crankcase-oil dilution. On this basis, a program of low-temperature tests has been laid-out which aims to determine, first, what conditions exert the most influence on the questions under investigation and then to obtain quantitative measurements with each fuel under the conditions thus determined. The initial stages of this investigation are being carried out in the laboratory, where easy and accurate control of conditions is possible.

In general, the laboratory investigation aims to discover the conditions under which a richer mixture is required with one fuel than with another for a given performance. When these conditions are found and the difference in the fuel-consumption is measured, the results are applicable to service conditions by determining through actual road-tests, or other means, how often these conditions occur in ordinary driving. As an example, suppose one of the fuels required a richer mixture than another only during starting cold and accelerating to normal speed. If this richer mixture were obtained through the use of the choke and the carbureter adjustment were not changed, the difference in the fuel-consumption would depend principally on the amount of cold-starting and acceleration included in the ordinary day's driving under cold-weather conditions.

A definite program for road tests under winter conditions has not been formulated as yet, because the details of this program will be influenced largely by the results obtained from the laboratory work.

THE DISCUSSION

R. E. Carlson:—The paper, as read, covers the work under summer conditions and states briefly the purpose of the work under winter conditions. This winter program will be supplemented by such road tests as are required, the details of these road tests being dependent largely on the results obtained from the laboratory work under winter conditions. Fig. 11 is a schematic diagram of the arrangement of the apparatus for the laboratory tests.

We have made a very large number of tests in the laboratory under various conditions of load and temperature. We have also made a number of acceleration tests.

The curve at the left of Fig. 12 shows the comparison of the four fuels at a jacket temperature of 85 deg. cent.

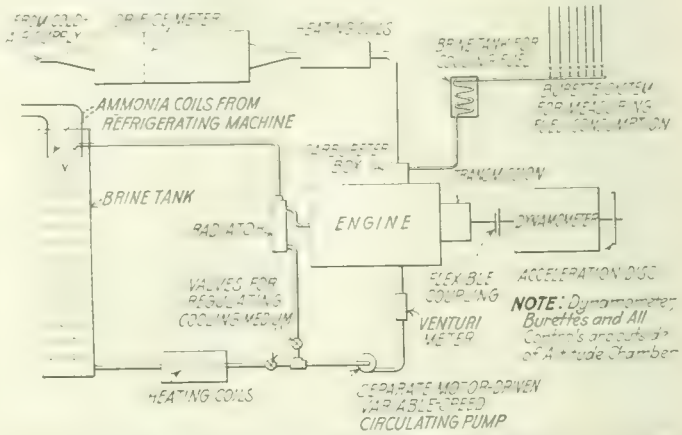
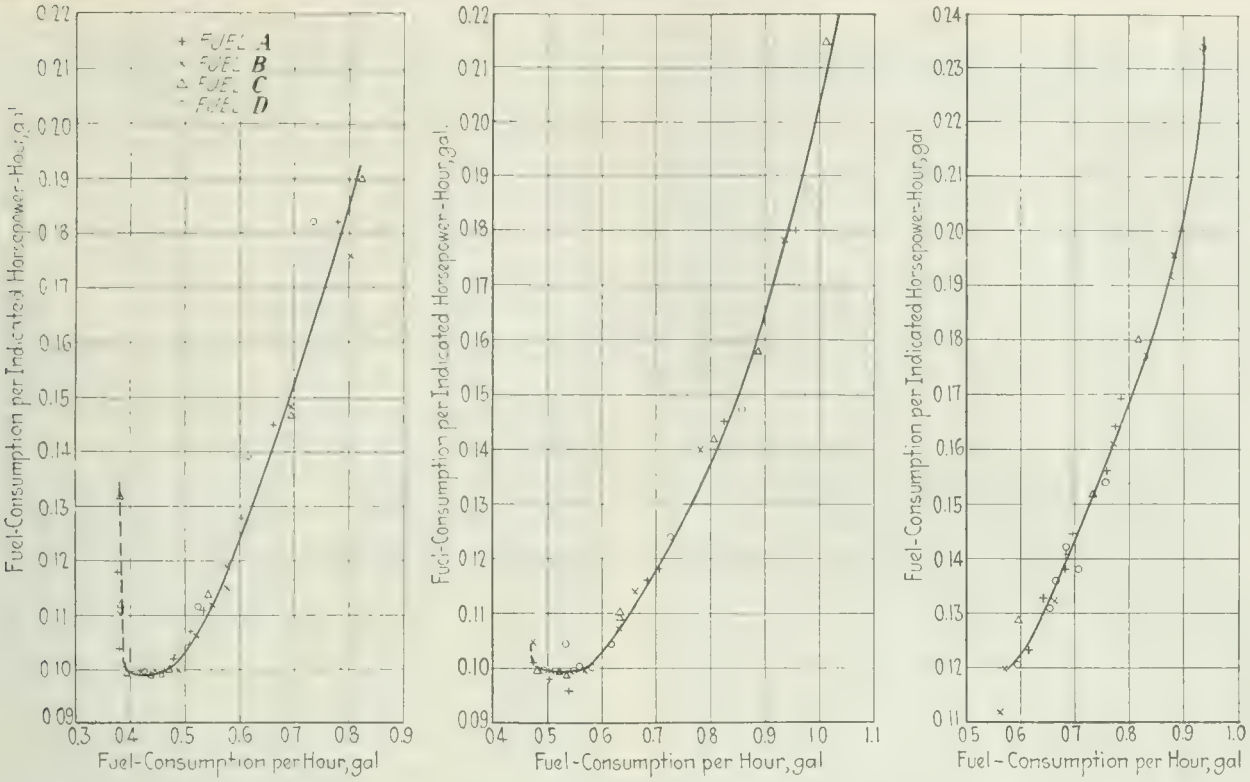


Fig. 11—Diagram Showing the Arrangement of the Apparatus Used in the Low-Temperature Laboratory Tests



Jacket Temperature — 10 Deg. Cent. (14 Deg. Fahr.) Air Temperature 65 Deg. Cent. (149 Deg. Fahr.)

Jacket Temperature 85 Deg. Cent. (185 Deg. Fahr.) Air Temperature 65 Deg. Cent (149 Deg. Fahr.)

Jacket Temperature 10 Deg. Cent. (50 Deg. Fahr.) Air Temperature — 15 Deg. Cent. (5 Deg. Fahr.)

FIG. 12—COMPARISON OF THE FUEL-CONSUMPTION OF THE FOUR FUELS UNDER DIFFERENT TEMPERATURE CONDITIONS, THE LOAD AND THE SPEED BEING CONSTANT

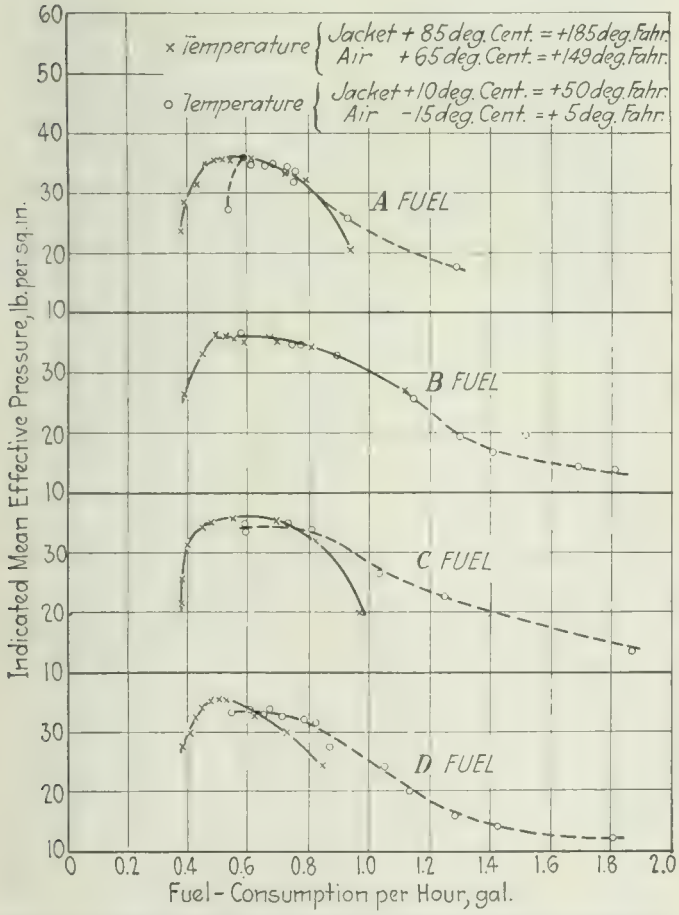

× Temperature { Jacket + 85 deg. Cent. = +185 deg. Fahr. Air + 65 deg. Cent. = +149 deg. Fahr.
○ Temperature { Jacket + 10 deg. Cent. = +50 deg. Fahr. Air -15 deg. Cent. = + 5 deg. Fahr.
A FUEL
B FUEL
C FUEL
D FUEL
Indicated Mean Effective Pressure, lb. per sq. in.
Fuel-Consumption per Hour, gal.

FIG. 13—COMPARISON OF THE RELATION BETWEEN FUEL-CONSUMPTION AND INDICATED MEAN EFFECTIVE PRESSURE UNDER DIFFERENT TEMPERATURE CONDITIONS

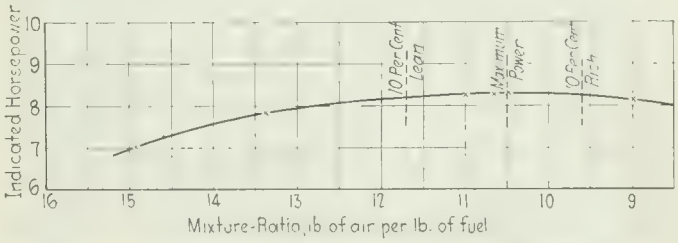


FIG. 14—CURVE SHOWING THE RELATION BETWEEN THE INDICATED HORSEPOWER AND THE MIXTURE-RATIO

(185 deg. fahr.), air temperature 65 deg. cent. (149 deg. fahr.) and load of 3 b. hp. at 600 r.p.m. It will be noted that the points for the four fuels fall closely together at the lower portion of the curve, which represents normal operation so far as fuel-consumption is concerned.

The central curve gives the same comparison with the same brake-load, but at a jacket temperature of minus 10 deg. cent. (14 deg. fahr.) and air temperature of 65 deg. cent. (149 deg. fahr.). The curve at the right gives the same information at a jacket temperature of 10 deg. cent. (50 deg. fahr.) and air temperature of minus 15 deg. cent. (5 deg. fahr.). It can be seen from these curves that there is practically no difference between the four fuels under conditions of constant load and constant speed.

Fig. 13 is interesting because it brings out the fact that it is possible to run a very much richer mixture under cold-temperature conditions. The crosses represent readings taken under normal temperature conditions, the jacket at 85 deg. cent. (185 deg. fahr.) and the air temperature at 65 deg. cent. (149 deg. fahr.). The circles represent readings taken with the jacket at 10 deg. cent. (50 deg. fahr.) and the air temperature at minus 15 deg. cent. (5 deg. fahr.).

From Fig. 14, it will be noted that the power curve is very flat over a considerable range of mixture variation. This curve perhaps will make more clear the difficulty experienced in attempting to obtain the optimum carbureter-setting under summer conditions inasmuch as this power curve, which was obtained from laboratory tests, was taken with the jacket at 85 deg. cent. (185 deg. fahr.) and air temperature at 65 deg. cent. (149 deg. fahr.).

Mr. James, under whose supervision this work has been carried on, and from the standpoint of the Bureau of Standards deserves the credit for the conception of this work, will discuss some points that are of interest in connection with the dew-point temperatures of these four fuels.

W. S. JAMES:—The point I would like to make can be illustrated by an example. Suppose the people on Mars wanted to know the temperature of the Earth, and sent a man to find out. Suppose he landed at the north pole, went back and reported that the Earth was cold. Suppose another Martian was sent out and that he landed at the south pole. He also would report that the temperature of the Earth was cold. The people on Mars might reason that, as the two extremes of the Earth were cold, the whole Earth was cold. If, later, some other Martian happened to land on the Equator, he would come back with a different story, and the people on Mars would have to revise their conclusions as to the temperature of the Earth. I am wondering whether we are not almost in the same situation, when considering the results now available from the winter work.

For instance, we tried to cover the two extremes. The engine was operated with jacket heated to 85 deg. cent. (185 deg. fahr.), and the air entering the carbureter to 65 deg. cent. (149 deg. fahr.). Under those conditions, reasonably good vaporization would be expected. Then the engine was operated with the jacket water at 10 deg. cent. (50 deg. fahr.), and the air entering the carbureter at minus 15 deg. cent. (5 deg. fahr.). Under both conditions, no differences were found among the fuels.

In going over these results there is an interpretation that may be as incorrect as that which the Martians might have made of the temperature of the Earth. Although there is as yet insufficient evidence to draw definite conclusions, *there may be a difference* between the fuels within the range indicated between the extremes mentioned.

From an examination of the dew-points, as determined by D. P. Barnard, 4th, when using Prof. R. E. Wilson's method, a 15 to 1 mixture of Grade-*D* fuel would be dry at approximately 46 deg. cent. (114.8 deg fahr.); and a similar mixture of Grade-*A* fuel would be dry at 9 deg. cent. (48.2 deg. fahr.). Therefore, if the manifold temperature is above 46 deg. cent. (114.8 deg. fahr.), there can be complete vaporization of all fuels.

It is agreed generally that the differences in economy that are likely to be obtained with several fuels are more affected by the distribution of the fuel to the cylinders than by any other factor. If the engine is operating with an intake-manifold temperature that can give complete vaporization, the manifold may be distributing mainly gas or vapor in the case of each of the four fuels; and, with manifolds as generally constructed, there is very little doubt that there would be little difference in distribution among the four fuels. On the other hand, when running at low temperatures, the intake-manifold temperature was about minus 13 deg. cent. (8.6 deg. fahr.) in the case of all four fuels. Therefore, it may be that all four fuels were practically liquid while being distributed by the manifold.

Since the differences in the amount of vapor formed respectively in the four fuels probably would be relatively small, the differences in their distribution also would be small. However, the fact that a manifold will distribute vapor alone, or liquid alone, does not prove necessarily that the same manifold will distribute a mixture of vapor and liquid as well as either one alone. Whether this is true or not, we do not know. We want to emphasize the fact that this work is incomplete. There is a possibility that, because we have gone completely from one extreme to another, we have missed the place where the difference lies. From the results we have obtained so far, I believe we cannot estimate very well the magnitude of that difference.

This may also be an explanation of the fact that no difference was found in the operation of the cars during the summer tests. In each case, and as is general in summer, the engine was warmed-up; the exhaust-manifold was hot and the air entering the carbureter from the hot-air stove was probably about 60 or 65 deg. cent. (140 or 149 deg. fahr.). The work that has been done under winter conditions confirms the results obtained under summer conditions, and it is rather hard to predict at this time what will happen during the warming-up period of fall and winter operation.

I think that these considerations do not make it impossible to draw conclusions with regard to summer operations, but they may have an important bearing on the winter work.

DR. VAN H. MANNING:—Mr. H. M. Crane has contributed very largely to this work. He has gone through the process of education that all of us have been through. It took some time to educate the automotive and the oil industries in regard to the necessity of this program that is now under way. I can recall that, in 1920, complaints were being made that the oil industry was not furnishing the automotive industry the kind of fuel it wanted. The subject came up at our Chicago meeting as a topic for discussion. I objected to the title that was submitted by the Society in that it indicated that it wanted to establish a uniform automotive fuel. My reply has been, and is today, that the oil industry will keep pace with the automotive industry. What is needed is cooperation. We have shown in this work that it can be had.

In 1911, there were 750,000 cars in use; today there are about 12,000,000. You have increased over 1250 per cent in your production while the oil industry has kept pace with you with an increase of only about 100 per cent in crude-oil production. In 1911, we had 315 bbl. of oil available for each car. In 1922, we had 47 bbl. That is the answer to the question regarding the progress that is being made by both industries.

T. J. LITLE, JR.:—The crux of the whole matter is in the summary of the report in which it is stated that the drivers preferred the Grade-*B* gasoline, did not particularly object to the Grade-*C*, but in most cases found difficulty in using the Grade-*D* fuel. I find that to be a pretty general comment on the tests that have been discussed. The high crankcase-oil dilution, and other things, have indicated the desirability of resuming the test in the winter months. If we have to use this Grade-*D* gasoline we may develop schemes to use it; but, at present, we do not like it very much. I think that is the consensus of opinion among engineers.

I think we have not been told directly by the oil industry that it cannot produce a better gasoline. Some

oil-refiners are not using the cracking method for the purpose of producing more gasoline. Some of them are using it to a limited degree. The patent situation, of course, enters into the matter. Some companies are known simply as skimming companies. I wonder if the oil companies are in the position of some manufacturers who are still using obsolete machinery. An uptodate manufacturer scraps his old machinery every few years and buys the latest and most improved type.

Will we have to use this Grade-*D* gasoline? Is that necessary to the proper operation of the industry? We do not want to use it. We wish the refiners would make a great effort to improve the quality. In the automotive industry, we have had some cases where we decreased the price and increased the production. I wonder if that is possible in the oil industry. It seems to me that is what we must know to discuss this problem intelligently.

F. A. HOWARD:—It is just a dollars-and-cents question with the oil industry what the grade of gasoline is, within the limits of supply. Aside from the patent situation, the elements of importance in cracking are the investment and the operating costs.

It should not be lost sight of that cracking is no solution of the problem we are discussing now; that is, of the relative cost and value of the Grades-*A*, *B*, *C* and *D* fuels. Cracking merely produces what might be described as a synthetic crude-oil. If everyone were cracking oil, there would still be the same production difference and the same price-differential between gasolines of Grades *A*, *B*, *C* and *D*; so, cracking is merely to be regarded by the automotive and the petroleum industries as, in effect, an increase of the supply of crude, in a limited sense.

Referring to the history of this joint industry of ours, the transportation of the American public in automotive vehicles, I divide it into three periods. The first period terminated about 1914. In this there was a constant change, or "degradation," in the quality of gasoline, corresponding with the increased demand for that product. About 1914, there came a period of organized resistance to that change. In our own territory on the Eastern seaboard, that first took form in the statutes of South Carolina, in which it was attempted to fix the specifications of motor gasoline at 92 per cent distilled off at 302 deg. fahr.; that is, an 8-per cent residue above 302 deg. fahr. The gasoline that was actually being made on the Eastern seaboard at that time ran about 25-per cent residue at 302 deg. fahr. The Grade-*B* gasoline of the tests under consideration runs perhaps 40 per cent residue at 302 deg. fahr.

This period of resistance to change in the quality continued, and was reflected by legislation, as well as by more or less unpleasant relations between the representatives of the automotive and the petroleum industries, until about 3 years ago. Then the second period began—the period of trying to substitute information for prejudice, to find the facts; the period of scientific investigation.

We have had a movement that has been almost like the swing of a pendulum. It has been increasing in speed. Our knowledge, and our efforts toward increasing our knowledge, have been increasing at a very rapid rate for the past 3 years. What I am afraid of now is another period that I think none of us would like to face. That is another period of resistance to change based, this time, on a limited amount of scientific knowledge and investigation.

It seems to me that a scientist or an engineer, in so far as he subscribes to the true doctrines of science, has two duties in the world; one is to ascertain facts and the other is to preach the scientific spirit to everyone with whom he comes into contact. That spirit can best be defined by the two words, humility and tolerance, an abiding faith in one's own fallibility and a respect for the opinions of others.

If that is a true definition of science, it seems to me that the Research Committee of the Society has, up to the present, actively entered only half of its field; and the same is true, I believe, of our petroleum research organizations. It has very actively entered, with excellent results, the field of really increasing our knowledge on the subject in hand. It has, however, taken no active part in teaching the world that everyone, including the scientists themselves, is fallible and that any man who is in good faith trying to do a good thing may be right. I am thinking of that concretely, as applied to any attempts to determine and to fix, or to impose upon others, our ideas of what is the correct quality of gasoline or of lubricating oil.

The petroleum business is a very peculiar one. We like to call ourselves manufacturers, and sometimes we like to call ourselves chemists; but that is stretching both terms pretty far. Practically, what we do is to pass along to the automotive industry something that is sifted out of a deposit that nature gave us. That is about all. We polish it up a little bit; and sometimes we wish we had not polished it that much. Fundamentally, the automotive industry is merely getting what the Lord provided in the way of natural crude-oil. Any other conception of a basic-fuel industry would be wrong. No fuel industry could exist that was based on anything that was really a manufacturing industry. I think I said once before that the purpose of fuel is to save human labor and not to represent an expenditure of human labor. Therefore, fundamentally, this petroleum business is a business merely of passing along, with as little change as possible, what comes from the ground.

Another aspect of this rather peculiar situation is that the oil industry is not built on bed-rock. Both the oil and the automotive industries are built on the shifting sand of being able to find from year to year increasing supplies of material that will come out of a hole in the ground in a liquid form so that it can be pumped to its market. No one knows what the future holds for us in that direction. It seems to me that, considering all of these angles of our joint industries (they are almost cooperative industries from a business aspect at present), we are facing a situation that demands, more than any industrial situation ever demanded in the past, the truest use of the scientific spirit that is, we must not only determine our facts, but we must preach to the legislators, to the public and to everyone else, that non-interference, a respect for the other man's opinions, is the thing by which they must guide their conduct.

C. S. KEGERREIS:—Several factors must be evaluated before the public can use heavy fuels satisfactorily. The following are some relative data on oil dilution when using kerosene. The oil was measured when poured into the crankcase and again on removal. In all cases the specific gravity was noted. The oil was composed of 50 per cent Mobil B and 50 per cent Mobil A. The engine was operated under different loads, up to 50 per cent load, for approximately 15 hr., during which period the mixture-ratio was changed from lean to rich so that poor operation resulted at either extreme. The result on kerosene, which is heavier than the Grade-*D* fuel,

shows about 0.7-per cent dilution per hr. based on the specific gravity.

As yet, we do not know the critical limit for dilution; that is, the point where a marked detrimental effect on the engine can be noticed. We often hear gossip about burned-out bearings caused by oil dilution; however, actual evidence on these cases is lacking. To establish this critical point definitely, more research must be conducted along this line before the public can use a heavy fuel.

The public must use the heavy fuels soon, and hence the automotive industry must develop carburetion systems that will prepare the fuels satisfactorily for efficient combustion. If the petroleum and the automotive industries are really to cooperate and supply us with a fuel with which good performance can be obtained, I think this must come gradually over a period of perhaps 4 or 5 years. By improving the cars and decreasing the volatility of the fuels, the public will get the same satisfaction out of the Grade-*D* fuel as we are now obtaining from such a fuel as the Grade-*B* type. The useful life of a car is about 5 years. The cars now built, and those to be built during the next few years, will not be too troublesome in starting or in acceleration and general performance.

I. K. GILES:—The entire problem is an economic one, not only from the point of view of the oil refiner, but from those of the car builder and the consuming public. The average refiner is desirous of producing a satisfactory fuel. He fully intends to do so, but he has to have the evidence to show what a satisfactory fuel is. Fortunately, the various people interested are now working in harmony and gathering data on what they can find out about satisfactory fuels. As the work goes on, there will be certain contradictory results. Progress cannot be delayed by taking an indefinite amount of time to try to explain these contradictory results as they occur; therefore, the final result will have to be a general compromise. After the work is "completed" and the various interested parties have had a chance to go over it, the final task will be the proper interpretation by competent people of the results obtained. Then specifications should be drawn up that will yield the greatest possible satisfaction to the oil producer, the refiner and the consuming public.

O. C. ROHDE:—My first question is in regard to the effect of distribution through the different cylinders, as it relates to this problem. We know that if we take a fuel of low volatility and have an engine that gives poor distribution, our difficulty will be emphasized; conversely, if we have a fuel of high volatility, it will be minimized. In the more exact investigations, has this question been given consideration, and how has it been approached?

My second question has to do particularly with the winter work, where the element of starting becomes a factor. How much attention was paid to the gap-setting of the spark-plugs used in these tests, so that it would be uniform and give uniform starting conditions?

H. E. PENGILLY:—I think that the results of this test, when averaged as a whole, taking into consideration all the variables, have shown the best economy of the Grade-*B* gasoline, which is approximately the gasoline we are getting at present. That is a point in carbureter setting. In other words, those conducting the tests were familiar with the gasoline and probably set the carbureters to get the best results out of it. The design of engines has been based on gasoline of about that character for at least 2 or 3 years. In other words, the builders of the cars, knowing what fuel they had to use, have attempted to get the best results possible from it. Some car-makers have gone too far in manifold design in an attempt to handle heavy gasoline. They would like a little heavier gasoline to show the best fuel-economy; whereas, others who have lagged behind in this respect are not satisfied with the gasoline that they are getting today.

MR. CARLSON:—With reference to the question concerning distribution, the primary object of this investigation was to obtain a comparison of the four test-fuels when used in average cars. For this reason, throughout the tests, we have used the cars selected without changing their original equipment. We have made no attempt to study the effect of the four fuels on distribution when different manifolds are used.

As to spark-gap setting for starting under winter conditions, we have not carried on starting tests to date. Our work has embraced runs under various load and temperature conditions, as well as acceleration runs. We are running crankcase-oil dilution tests. We expect to run tests to determine whether there is any difference in the four fuels with regard to ease of starting.

PRESIDENT B. B. BACHMAN:—What we are really after is to find out what effect a change in volatility would have on the gasoline consumption of the cars that are in use. We can expand the research program to cover a great many interesting things, but that is the fundamental question we have been trying to answer. We have some 12,000,000 cars in operation.

HERBERT CHASE:—It might be worth while to give, in connection with the table of results, a record of some of the characteristics of the engines that were tested. If it is not permissible to give the names of the builders, it might at least be possible to say what kinds of manifold were employed, especially as to their "size" and the method of heating, and to give some other particulars about the engines used in these cars that will enable one to conclude what factors influenced the results obtained.

PRESIDENT BACHMAN:—My impression is that there were some restrictions with regard to the information that we could supply.

DR. H. C. DICKINSON:—In that connection, those tests were run by 10 of the companies. Nine of them turned in their results pretty promptly, one company reported recently. The work was done as has been outlined; it was laid-out by the Research Department and the plans were followed pretty generally as they were laid out. After the work was completed we had a conference with representatives of each one of the companies involved. Two or three of the companies, for reasons they thought were good and we had to accept, wished to have no results published that would make it possible to identify the different makes of car. The main reason was that, while they were willing that any engineer should have the results, they were not willing to throw them open for use by the advertising departments of either their own or other companies, a reason that, perhaps, is sound.

With reference to winter tests, the program as laid-out for the summer tests will probably be carried out in duplicate in February, 1923, with slight modifications. Most of the companies that ran the summer tests have already signified their willingness to repeat the operation during the coldest part of the year, and we expect that this work will be begun as soon as we can prevail upon some of our petroleum friends to supply the necessary fuels. There seems to be some little difficulty about getting promptly a supply of the fuels we want for the purpose.

The Motor Truck and Our Railroads

By Elisha Lee[1]

Annual Dinner Address

I WELCOME very sincerely the invitation that gave me the opportunity of being here tonight. Naturally, for personal reasons, the honor that it carries is keenly appreciated. Beyond that, I find a deep source of satisfaction and assurance in the thought that you have asked a railroad man to address you during the course of your Society's annual meeting, and, I believe, as the only speaker outside the ranks of your own profession. May I express the hope that this will serve to symbolize the idea that the railroad and the motor vehicle are not rivals seeking to crowd each other out of the field of patronage, but are agencies capable of developing side by side and of finding their own broadest field in joining resources for the perfecting and rounding-out of the public service of transportation.

At the outset I wish to express my most sincere and profound admiration for the magnificent achievements of the American motor industry. The story of those achievements, practically all wrought in the short space of 20 years, and a large proportion of them in less than 10, constitutes a record for the marvelously swift creation of new wealth, capital and work, and for the elevation of the living standards and ambitions of many millions of people, which I believe cannot be paralleled in history.

In making that statement, I do not sacrifice any of the pride I have always felt in my own calling, and in the railroads as the great arteries of the Nation's life. But I am obliged to realize that within two decades the American automotive industry has risen from practically nothing until today, with all its operating vehicles, its manufacturing plants, its selling establishments, its fuel, storage, service and repair-stations, it represents, according to the estimates of your organizations, a substantially greater investment of capital than do the railroads and employs more hands, in these respects outstripping the growth of the railroads over nine decades.

Those are facts to which none of us should shut our eyes, least of all railroad managers. They are also facts from which we should be very careful to avoid drawing dangerously wrong conclusions. One of these conclusions, which from its novelty and spectacular appeal commends itself only too easily to many people, is that motor vehicles and concrete highways are destined to erase the railroads from the map. The truth, I believe, is that they are destined to add very greatly to the utility and efficiency of the railroads by rounding-out and completing the rail service, and relieving the railroads of certain forms of service that are burdensome and costly when performed over fixed tracks and with the necessarily heavy equipment of the steam lines, but can be made attractively profitable to the loose-footed, free-moving motor car. This is the aspect of the matter toward which, in my opinion, both the motor industry and the railroads, in their own true interests and in the interest of transportation progress, should endeavor to guide public thought and discussion.

Experience shows that radically new ways of doing things tend to create new fields of their own rather than encroach greatly upon what is older. For instance, we still write letters and use the mails in spite of the telegraph and telephone; we doubtless write far more letters than we would need to write had electrical communication not been invented to add enormously to the general volume of business activity. We still write with pens and pencils in spite of typewriters. We still write in longhand notwithstanding the seemingly great advantages of shorthand. We use pens dipped in ink in spite of fountain pens.

The telephone has not wiped out the telegraph, as many people thought it would. The telephone's chief development and utility have been in fields the telegraph could never have touched. And the telegraph, on the other hand, retains unchallengeable superiority over the telephone for many very important purposes, and seems likely to do so indefinitely.

Wireless telegraphy has made its own place in a very important field of utility and service where the wire systems could never have functioned; but in the fields where the wire telegraph was commercially established, the wireless has never made measurable headway. The radio telephone seems to be following a similar course with respect to the switchboard systems of telephony.

To take a different illustration, there are many more horses in the United States at the present time, the census tells us, than in 1900, when, as you may recall, prophets were busy proving how horses could soon be dispensed with as a result of "horseless carriages."

Many other similar examples might be given. They all seem to demonstrate one general truth, which is that the human race, in its march of progress, constantly accumulates new resources and facilities; adopts the new readily and swiftly, but rarely discards, and then only very slowly.

Motor Vehicles and the Railroads Not Competitors

So I think it is likely to be with the motor vehicle and the railroad. The part of the motor vehicle, in rendering transportation for hire, is not to do what the railroad is already fitted and equipped to do with full success and satisfaction; it is to do what the railroad is not able to do at all, or else does only with difficulty and imperfect success.

Events to the present time certainly bear out that view. There are now, it is stated, nearly 12,000,000 motor vehicles in the United States, all busily engaged in producing transportation in enormous volume. Yet since 1900, when the motor industry may be regarded as having its rise, the freight traffic on our railroads, measured in tons and passengers carried one mile, nearly tripled. In the last three years, the demands for transportation made upon our railroads have exceeded those of any previous era, and it is common knowledge that the question how to increase the carrying capacity of the railroads is the Nation's most pressing economic problem at the present time.

We thus have what superficially seems to be an anomaly in the rise of an immense new transportation agency simultaneously with unprecedented demands upon the services of the older agency. The explanation, of course,

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is the very obvious fact that the vast bulk of the transportation rendered by motor vehicles is in entirely new fields. It constitutes additions to, rather than substitutions for, that previously rendered by the railroads. For that reason, when the new business booms developed, the railroads felt the pressure almost as though commercial motor-transport did not exist. Indeed, the vast impetus to motor-car building in the last few years was one of the most notable causes of the increased demand upon the railroads for service. So we have another interesting situation in the fact that the expansion of a new agency of transportation has actually added greatly to the demands upon the old.

In discussing the relationship of motor transport to the railroads, we necessarily have in mind the possibilities for the further development of motor vehicles in the field of transportation for hire. I of course share the realization of railroad officers, generally, that this activity, although already of important scope, is still in a state of comparative infancy and is entering upon what should be a period of lusty and vigorous growth. Nevertheless I have indicated the opinion that the resulting problems, as relating to the railroads, will not, except in secondary degree, be those of competition, but chiefly those of coordination.

For holding those views, I have a very simple reason. Such profits as the railroads are able to make at all come practically altogether from the mass transportation of freight and passengers over at least considerable distances; in other words, from what we may term the "wholesale" departments of transportation. This is just the form of service in which experience shows that trucks cannot consistently earn real profits. On the other hand, those forms in which trucks can and do make money are almost invariably the strictly "retail" forms, in the rendering of which railroad operation practically always involves losses, and sometimes very heavy ones. It is very important to note in this connection that the demands of modern large-scale industry for a constantly increasing volume of mass transportation are irresistibly compelling the railroads to adapt their motive power, cars, structures, terminals and operating methods more and more to the "wholesale" forms of service and, inevitably, less and less to the "retail" forms. That supplies the keynote for any sound consideration of the economic coordination of rail and motor transport.

The question of competition in reality seems seriously important from only one point of view, and that is the enlisting of the assistance of the leaders in the automotive industry in discouraging futile attempts at losing forms of competition. Such experiments are harmful in two ways. They reduce railroad earnings while they last, and waste and dissipate the energies of truck operators that might be utilized in productive channels. I am satisfied that the railroads and their patrons urgently need the cooperative services of both motor trucks and motor passenger-lines, and can, therefore, ill afford to see these forms of enterprise go to waste in fruitless and needless efforts at competition with transportation agencies that are already functioning successfully. I will endeavor to lay before you some of the specific ways in which it seems to me promising opportunities lie for bringing about a coordination of motor and rail services, with resulting advantages to both, as well as to the using public. Please consider my views broadly, as being personal conclusions and not as necessarily representing formally adopted policies of the railroad system with which I am associated or of the railroads in general.

Presumably, we all agree that, as a fundamental to any constructive approach, there must be open-mindedness on both sides. Automotive interests must cease to defend or encourage cut-throat sporadic forms of competition, while the railroads must be ready to relinquish to the motor trucks and passenger buses those forms of service in which the latter can clearly demonstrate superiority. There are truck dealers who will sell almost anyone a truck on installments, to operate almost anywhere, regardless of whether the venture is sound or not. Such a policy, which it is certainly within the power of the manufacturing interests to curb or correct, is neither more nor less short-sighted than that of the unprogressive railroad-official who blindly refuses to surrender a dollar of gross revenue, regardless of net results, on the principle that a railroad can never afford to give up anything or recede from any field.

Opportunity for Coordination

It seems to me that one of the most important opportunities for useful and successful coordination of motor and rail facilities may be expected to lie in organizing smooth-working freight pick-up delivery motor-services in the larger cities, for the less-than-carload traffic, to be operated in connection with inter-city hauls by rail. Such an arrangement would extend the scope of rail transportation by making it a really complete service from the premises of the shipper to the premises of the consignee. It would allot to each transportation agency employed the portion of the service that it is pre-eminently fitted to perform; to the truck the terminal work, and to the railroad the line-haul. This subject is of vital importance to the railroads, their patrons and the builders of motor vehicles, alike. If such a service could be worked out for the larger centers of the Country generally, it would constitute one of the most momentous advances ever made in the handling of railroad traffic, and create an economically sound market for the product of the motor-truck. makers.

In approaching this question it may be noted that the tendency usually is to dwell largely upon the possibilities of reducing the cost of distribution, through the establishment of such a system of store-door collection and delivery, in the sense of making possible a structure of through-rates that would be lower than the combination of the existing rail-rates and the present costs of collection and delivery at each end. It may be doubted whether that is really the best "selling-point" upon which the automotive interests can focus attention, or whether it is actually capable of immediate realization. It must be remembered that to inaugurate a service such as we are talking about, it will be necessary to enlist the aid of considerable new capital. A service of the character contemplated would certainly be a vast improvement over the haphazard facilities for collection and delivery now usually at the disposal of shippers and consignees who do not have their own trucks. It would constitute a notable addition to the present service and should be worth a fair and reasonable price. It is difficult to see upon what other basis the needed capital can be attracted.

In convenience and speed such a service would lie midway between the present ordinary freight and the express. It would be substantially a semi-express service, affording complete through transportation, rendered by a combination of motor truck and freight train instead of by a combination of truck and passenger train. The aggregate charges would of necessity have to be adjusted in proper recognition of the character of the service, always bearing in mind that new capital must be attracted if trucks are to be purchased and operated.

There would be many economies outside of the rates themselves. Among them may be enumerated the greater dependability of service, the reduction of losses in transit; lower insurance-rates; greater ease in making shipping arrangements and paying bills; and a reduction in the time goods are on the way, which would amount to a saving of interest on idle capital. The shortening of the time in transit would also permit the carrying-on of business with smaller stocks, thus in another way reducing capital charges.

In other directions such a system of collection and delivery would effect many savings which, although difficult to measure exactly, would be nevertheless real. Among them may be mentioned the more efficient use of the public thoroughfares, lessening the losses and delays now incident to the street congestion and crowding that are so marked under the present totally unorganized trucking methods in general use.

The question arises whether a terminal trucking system of the kind under discussion should be operated by the railroad companies or by independent enterprises working in cooperation with them. This matter would require careful study to be answered decisively, but in the light of present knowledge there appear to be at least two important considerations favoring independent operation. One is that the railroad business is already so vastly complicated that it is very debatable whether it is desirable to add another department, requiring expert knowledge, to the functions and duties of management. The other is that, if identified with the railroads in ownership, the trucking operations would be more likely to be subjected to hampering and restrictive regulation than if independent.

Should there be a single trucking agency in each city, or several more or less competitive? The former seems to be the general rule in England, where, by the way, the collection and delivery system appears to have been working-out very successfully. For us I am not certain that the single or unified agency scheme is the best. Without committing myself definitely, I may say that there seem to be at least some good arguments for preserving a degree of competition and also for maintaining the identity, all the way through, of the services of the separate railroad lines. That identity would be largely lost if every shipper and consignee, in a given city, transacted all transportation business through the same local collection and delivery agency. On the other hand, if there were separate agencies, cooperating with each separate line of railroad, the identity and individuality of the various rail lines, and of their services, would be preserved.

I presume that many of you are aware that this system of store-door collection and delivery of less-than-carload freight, as part of a through inter-city service, has already been introduced in this Country. While still functioning only in a limited way, it may fairly be regarded as past the purely experimental stage. Certainly it merits careful study and consideration by the directing minds in the automotive industry. It hardly need be added that the adaptability of freight containers to the handling of less-than-carload freight on combined motor and rail hauls, should receive further thorough consideration, in connection with this general subject, from the viewpoints of both truck and railroad operation.

Highway-Building Policy

Outside the large cities, much interest in the coordination of rail and motor facilities centers upon the possibilities of extending the use of motor trucks as lateral feeders to the railroads, thus placing the farm products of vast and fertile, but sparsely settled, territories into better communication with the railroad lines. We may as well face the fact that any very early realization of such hopes, upon any considerable scale, will necessitate a change in the policies now chiefly dictating the building of our hard-surfaced highways. There seems to be a positive mania today for building long-distance automobile and motor-truck roads, whereas the more urgent need is probably for shorter-distance lateral highways, bringing the more remote villages and countryside into better communication with the larger towns and railroad centers. But just now no one seems to be much interested in a road project unless it is advertised to run from ocean to ocean or Lakes to Gulf, or to create some other new and striking long red line on the touring maps. That appeals to the imagination, but it is very doubtful whether it constitutes, in the majority of cases, the best expenditure of the taxpayers' money. This same policy also has an important bearing upon the possibilities of extending motor-bus service for passengers into the territories not already served by railroads or by interurban electric lines. Our new highways, inviting motor travel, are not being built in those directions for the most part. Instead, thousands of miles of concrete and other expensive roadways have been built, and are under construction, paralleling the lines of the trunk-line railroads. These highways are the great routes of the longer distance motor buses. Their coming does not assist in giving transportation service to people who previously had none. To make matters worse, in many cases, especially in the Central West, the rail lines had already been paralleled, years ago, by interurban trolley-lines, so that the advent of the concrete road and its bus lines often simply provides a third agency of transportation where one would suffice. Thus, with a serious shortage of transportation for the Country as a whole, we are confronted with a remarkable excess of facilities in certain instances.

A very striking case that came to my notice because it developed in Pennsylvania Railroad territory involves a town of about 40,000 inhabitants, located 31 miles from a Middle Western city of some 400,000 people. The populations of and the comparatively long distance between the points make it evident that the volume of traffic could not be extremely heavy. Yet investigation shows that, analyzing the service in one direction only, there are 86 regularly scheduled movements of passenger vehicles daily, including steam trains on two railroads, cars and trains on the electric lines and a number of bus lines of the public highway. I suppose that none of the services is making, or possibly can make, money under such conditions. The railroads, if they consulted their own interests only, would abandon their passenger trains at once between those points. Please observe, in connection with this illustration, that multiplication of facilities has given to those two comparatively small inland centers a greater frequency of passenger service than is afforded between New York City and Philadelphia, where the world's densest passenger traffic, over any considerable distance, is handled. Also observe that the building of the costly highway, which added the buses to the previously existing electric and steam lines, did not extend transportation service of any kind into any new territory.

One of the important effects of building highly improved roads directly paralleling the main lines of the railroad has been to reduce the travel on local accommodation trains, operating over these lines, to the point

where they show very serious losses. Yet a sufficient number of people continue using these trains to make it evident that their complete abandonment would often be a genuine hardship. We have many cases of this kind on the Pennsylvania Railroad System, especially in the Central West where, as I have stated, mile after mile of concrete and stone roads is being built parallel to rail lines already paralleled by trolleys, while the lateral roads into the farming regions and more distant villages remain almost impassable in winter. Such a highway-improvement policy is a very serious matter to the railroads and their patrons, and seems well worthy of the most careful attention of and consideration by this Society.

Motor Rail-Cars

Before coming here tonight I was requested to discuss the adaptability of motor-driven rail-cars to passenger service on existing branch railroad lines of light traffic. My reply must be that the real answer to this question lies in the hands of the automotive engineers themselves. The railroad with which I am associated is carefully studying every new design brought out, as are many of the other roads. But thus far the type has not been produced that we can regard as fully and satisfactorily solving the problem. However, we are proceeding to give a practical try-out to a number of cars of the most promising type yet produced, and other lines are following a similar course.

I can give briefly the specifications of what the successful gasoline rail-car must, from the railroad manager's viewpoint, be and do to meet with reasonable completeness the needs of light branch-line traffic. It must be capable of carrying from 70 to 80 or more passengers, with suitable baggage, mail and express space. It must be capable of a sustained speed on a level track or ordinary grades of at least 40 m.p.h. It must be reversible and capable of operation from either end. It is needless for me to say that the problem resolves itself largely into the designing of an engine of sufficient power, probably at least 100 hp., with the necessary mechanical and electrical equipment that will allow control from either end and movement in either direction. That problem is in the hands of your profession. I have no doubt that it will be solved.

Limits of Motor-Vehicle Service

There is just one more subject upon which I would like to touch, and that is the limits of distance within which the motor truck, instead of acting jointly with the railroad, may be regarded as fitted to take-over merchandise freight service in its entirety. In my opinion, all freight service within city and highly developed suburban areas should be performed entirely by truck, except those special cases involving single pieces of such great weight as to necessitate the use of railroad equipment and roadbed. Otherwise, the railroads ought to be relieved altogether of intra-city business, so that their tracks within the municipal areas may be reserved entirely for the purposes for which they were constructed, namely, the rendering of the strictly terminal service required in connection with the line-hauls.

Outside of the strictly cosmopolitan districts, the question of determining the economic limits of truck operation resolves itself into one of determining the point at which the cheaper costs of truck service within terminal zones begin to be overcome by the greater efficiency of the line-haul by the railroad. The distance would naturally differ for every center. It may sometime have to be designated more or less arbitrarily, for every cosmopolitan district, by regulative authority. Possibly a fair average distance might be 25 miles around every large city. Within a circle of some such radius most of the less-than-carload work can be done more efficiently if performed entirely by trucks. Outside of it, the greater efficiency will be obtained by the use of trucks for collection or delivery and the railroad for the intermediate line-haul.

In this connection, as throwing some light upon the results of comparatively long-distance motor freight-service, when attempted on a considerable scale, it may be of interest to you to know that out of 100 to 120 trucks now running between New York City and Philadelphia, only one line has been in business more than 2 years. The road distance is about 95 miles. Trucking began 5 or 6 years ago, during the war-time congestion of the railroads, and was for a time sustained by the abnormal conditions then existing. The fact that only one of the earlier lines has survived to the present time certainly seems to cast serious doubt upon the financial soundness of large trucking ventures over distances of such length, even when favored by excellent road conditions and great density of traffic. In fact, so far as we have been able to ascertain, the only reason trucking continues on the present scale between these two cities is that losses of capital are constantly being made up by people who apparently are unfamiliar with what is entailed.

If we come to the designation of what shall be the trucking zones in and about municipal areas, by regulation, as is certainly not impossible, there is a closely related provision that should on no account be neglected. Whenever a certain zone is declared to be truck territory for less-than-carload freight, the railroads should be permitted to abandon their form of service within it entirely. Otherwise, the trucks will be in a position to take the cream of the traffic, the higher classifications of freight moving during favorable weather, and leave the railroads, which cannot legally refuse service, the skimmed milk, that is, the lower classifications and all the work in the winter storms. Such an arrangement is neither just nor conducive to good and dependable service.

Similarly, with passenger traffic, where there is not enough to support both rail and bus lines, does it not seem proper to determine which form of service shall be continued within specified zones and which shall withdraw? When the people permit the building of hard-surface roads directly paralleling the established rail-lines, and then permit and encourage the operation on these highways of bus lines, paying nothing for their roadway, and to such an extent that the revenues of accommodation passenger-trains do not cover half the cost of operation, should the people of those communities insist upon the continued running of the trains? Does it not seem fair to call upon them to decide which form of service they desire, and to abandon the other, especially when the railroads are being subjected to constantly increased taxation to help build such highways? That is a situation which many railroads are facing in different parts of the Country. It will invariably have the result of bringing about a movement for a general reduction in passenger accommodation-train service.

In discussing the motor truck, I have referred only to the less-than-carload freight service. My views upon trucking freight that is moving in carload volumes are

(*Concluded on p.* 180)

The Design of Commercial Airplanes

By E. P. Warner[1]

Annual Meeting Paper

THE author discusses commercial-airplane design in general terms, considering the subject under the main divisions of economy, safety, speed and comfort. Under economy, mention is made of possible reductions of first cost by designing for long life and reliability, the effect of the former on the depreciation allowance being obviously advantageous. Airplane size is debated also, the trend of progress being seemingly toward the giant airplane.

Safety is stated to be dependent upon reliability, structural strength, stability, control, fire prevention and reduction of risk of injury to passengers in the event of a crash. Minimizing the results of a crash is considered suggestively.

Speed is governed almost solely by the ratio of wing loading to power loading; hence, speed will always be kept as low as possible without loss of business to competing transportation enterprises. Among desirable measures to secure comfort, adequate ventilation and the elimination of noise are included.

IT has been a common error, in discussing those technical factors that enter into the design of the flying equipment for an air line, to neglect the specific conditions under which the equipment is to be used and to speak of commercial design as though it were a thing set apart from ordinary aeronautical engineering practice and as though, furthermore, it could be treated as a unit by standardized rules. Dogmatism is always dangerous, and never more so than here, where the whole sum of the world's experience, to say nothing of that of any individual, would be insufficient to justify the laying down of iron-clad specifications for successful design, even if all of the lessons of experience pointed in the same direction. As a matter of fact they do not, and it is hardly possible to generalize on the merits and demerits of specific details of practice. At best, we can only set forth certain principles bearing on what a commercial airplane should be able to accomplish, and say that under some particular conditions the compromise best satisfying those principles has been attained in some particular manner. The word compromise is used advisedly, for nowhere is it more true than in connection with the design of aircraft for commercial purposes that some highly desirable qualities find themselves placed in direct contradiction with others, and that hardly any gain can be attained without some sacrifice.

Obviously, the first step in deciding on the general characteristics of an ideal commercial aircraft is to decide on the qualities of performance which the finished product should show. Obviously also, the first of those qualities is economy. Air lines may operate under very grave handicaps of some sorts, but it is certain that they will not continue indefinitely to operate at a financial loss, and it is therefore a prime essential that the equipment used should be such that the costs of operation will be restricted to a figure making it possible to compete on reasonably equal terms with existing forms of transport. The only exception to the necessity for economy arises in the case where a government subsidy of great liberality exists, a subsidy that amounts to a government offer to pay all the bills and make the operating company independent of the traffic. Since it is neither desirable nor possible that such a condition should ever exist in the United States, it can be wholly disregarded in considering design for operations in this Country.

Second of the requirements, and indeed subordinate to no other in importance, for it is vital, is safety. It is futile to blink at the fact that the major source of difficulty in securing increased patronage for air-transportation facilities today is the danger that the lay imagination magnifies far beyond the reality. The elimination of the gap between the real and supposed risks of air travel is a problem in public education and in the dissemination of accurate information, but the reduction of the real hazard is a responsibility definitely to be shared by the designer of the airplane and by those charged with its operation.

Third we may list speed, in which air transport, like most other modern means of transport, finds its principal justification. Were there no reason to desire speed, the transcontinental railroads would never have been laid down, and goods and passengers would still be traveling in sailing ships around Cape Horn. Were there no reason to desire speed, British officials with business in Mesopotamia would still be making the journey from Cairo to Bagdad by caravan instead of traveling by air in fewer days than the old method would have required weeks. Air transport is at present, and is likely to remain, considerably more costly than surface transport, and it can only justify its existence by demonstrating a clear saving of time for a journey. The greater the difference of cost is, the greater the economy of time must be.

The fourth and last of these fundamentals is comfort. It may perhaps be said to be less important than the others, but that is very doubtful, for it is certain that only under the press of the most urgent necessity will passengers continue to travel in an unpleasant and fatiguing manner. The whole development of modern civilization has been in the direction of increasing comfort and convenience, and of converting the articles of luxury of yesterday into the accepted necessities of today. Study of commercial aircraft of the past and present suggests that some designers have started with the idea that the passenger requires nothing except to be placed on board of a projectile and shot through space with a maximum of velocity. The cases in which the desire for speed absolutely overweighs all other considerations will, however, be found few and far between.

The relative importance of these four qualities, or rather, to be more exact, the quantitative measures which can be considered as representing satisfactory attainment in respect to the various qualities, of course differs with the type of service. This is particularly true of speed, as we can never consider that permanently satisfactory conditions have been reached in respect to economy, comfort or safety, particularly the last two. There is, however, a particular speed which is best suited for each particular service. Obviously, to take a concrete example, high speed would be much more necessary on the route from New York City to San Francisco, where it is necessary to compete with a highly developed express-train service running 24 hr. each day, than between New Or-

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leans and Vera Cruz, or any other pair of points similarly served only by ships or by relatively slow overland transportation by a circuitous route. It is, of course, fundamental that economy and speed are in direct opposition, and the natural desire of those operating aircraft will therefore be to use the lowest speed that suffices to attract traffic. Only by competition among air lines themselves will speeds be forced up to levels materially above those now prevailing. At present, it seems impracticable to realize a commercial speed of more than 85 m.p.h. on lines running without subsidy, as the costs of operation at higher velocities than that become prohibitive.

Economy

To obtain economy means to reduce the sum set aside for the repayment of the first cost, as well as to reduce the costs of operation. The group of items relating to first cost, including depreciation and interest on the capital tied up in equipment, can be cut down by designing for long life and for reliability of service. The effect of long life on the depreciation allowance is obvious, and reliability enters in because airplanes and powerplants designed for a maximum of reliability can be kept continuously in service without laying up for overhauling and repairs, and the amount of capital tied up in reserve machines can thus be materially reduced. The differences in this respect among the companies now operating are really amazing, the percentage of reserve airplanes ranging from less than 100 to over 300. Since the average price of a commercial airplane is from $2,000 to $4,000 per passenger carried, it is manifestly undesirable to keep three-quarters of these costly machines idle in the hangars.

The first possibility that comes to mind in connection with design for durability is the increased use of metal construction. While there is no question that this is the best direction to pursue under some conditions, notably in the tropics, it is not at all certain that the life of an airplane for service in temperate climates is increased by the use of metal, while the cost in small lots indubitably goes up. In fact, a study of the records of operation suggests that the promotion of durability in airplanes is almost entirely a matter of a reduction of the crash hazard. The only part of the machine forming an exception to this rule is the fabric, which must of course be replaced occasionally, particularly if the airplane is kept out in the open. The cost of maintenance depends more on the general form of the airplane than on the materials employed, although some materials, particularly the metallic ones, offer an advantage in being less subject to distortion and warping than others, and therefore require less frequent realignment. For use in temperate climates at present, considerations of economy on the whole favor the use of a fuselage either of welded steel-tubing or of plywood, and a wing of wooden construction with plywood or fabric covering. On grounds of economy of maintenance, wholly apart from the running costs, the internally braced cantilever-wing offers a distinct advantage over any externally braced form.

Durability in engines is of course outside of the province of the airplane designer, except insofar as he is responsible for the choice of the powerplant. The recent extraordinary developments in increasing the effective life of airplane engines have indicated the possibility of largely reducing the economic importance of the item of depreciation.

Concerning economy of actual running expenses in the air, it is possible to be much more definite. Fuel cost is obviously reduced by the use of a minimum amount of horsepower per passenger. This is attained only at the cost of sacrifice of maximum speed and, as has already been pointed out, the extent to which speed can safely be sacrificed will be a function of the nature of the route. It cannot be too strongly emphasized, however, that for a given speed there is a wide range of choice in respect to the general arrangement of the design to be employed, and the common belief that certain types of airplane possess a tremendous inherent choice over others in respect to weight-lifting capacity is certainly erroneous. It happens that the first machines which were exhibited in this Country with any idea of commercial use were cantilever monoplanes and there has grown up, largely as a result of that priority of demonstration, a wide-spread feeling that the cantilever monoplane possesses distinct advantages over all other types for commercial purposes. As a matter of fact, a comparison of the results obtained with the machines operating on the various air-lines of the world shows very little difference between the cantilever monoplanes and the externally braced biplanes, and both of those types are in extended and successful use in Europe. As a rule, the thick-wing cantilever-type has a slight advantage in economy of operation at moderate speeds, while machines with externally braced wings give the better results when the operating speed is twice the minimum or more, because of the higher efficiency of thin airfoils at low angles of attack. In general, it can be said that an airplane having a maximum speed of 100 m.p.h. can carry 18 lb. per hp. and 9 lb. per sq. ft., giving it a landing speed of approximately 50 m.p.h. and a rate of climb high enough for safety in flying over reasonably smooth country. If 40 per cent of the total weight goes into useful load, the pay load, making an allowance for fuel for a 4-hr. flight and for the weight of one member of the crew for every 300 hp., should be roughly 4.5 lb. per hp.; this makes it possible to carry one passenger for every 40 hp. This is approximately equal to the best economy record that has been shown on any of the European commercial airplanes. The monoplanes have a distinct advantage over other types in respect to vision, but the discussion of that point can be postponed for treatment in connection with other matters bearing on comfort and convenience.

Airplane Size

The relative economy of airplanes of different sizes has long been a moot question, and is one on which violently different opinions have been expressed by the proponents of various schools of design. It is my belief that the subject has suffered from the excessively frequent introduction of the semi-fallacious square-cube law, and that the investigations of the theory of the effect of size have seldom given the large airplane its due. Experience shows the possibility of increasing the ratio of useful load to total weight as the size is increased, provided only that the weight is distributed along the wings in such a way as to reduce the flying stresses. This is sometimes objected to in military aircraft for military reasons, but there is no valid objection to the use of an efficient distribution of weight in commercial airplanes unless the powerplants are placed in inaccessible locations in an endeavor to distribute their weight. The ideal for the airplane of great size appears to be the cantilever monoplane with the engines arranged in two, three or four groups along the span of a supporting surface thick enough to permit a mechanic to pass inside of it from one powerplant group to another. The general plan is that of the Staaken-built Zeppelin monoplane.

There is another gain in percentage of pay load in that

the proportion of the useful-load capacity which goes into the weight of the chew is less in a large airplane than in a small one. The weight of a pilot must be allowed for in any case, even on a 100-hp. machine; a crew of two, including the pilot, suffices for anything up to 1000 hp., and three men should suffice for double that power. To keep the weight of the crew down to 0.5 lb. per hp., at least 700 hp. must be used if an assistant pilot is to be carried, as is in general wise practice. The very large airplane has the advantage not only in improvement of the weight ratio just noted, but also in the larger amount of space available for the passengers, resulting in more comfortable travel; in the greater safety which results from a multiplication of units and from the installation of radio and other navigating equipment which is too heavy to be carried in a three or four-passenger machine.

The coming of the giant airplane in commerce is prevented only by the lack of public demand for its services. Obviously, however great the saving in unit cost, there is no financial advantage in using machines so large that they cannot be completely filled. It must be remembered that the railroad has a certain advantage over the airplane in that the railroad's operating units are made up of multiple elements and that cars can be attached and detached at will. To gain a similarly variable capacity an air-transport enterprise must either have available machines of different sizes, the choice among them for a given trip depending on the amount of business, or must run small machines and many of them, starting several together at each hour when a departure is scheduled and distributing the load among them instead of carrying the same total amount in a single large airplane. The best plan appears to be to compromise, using machines of two different sizes. One of these sizes should be such that a single machine will take care of the normal traffic on a single trip with about 10 per cent of the seats unoccupied, while the other should be much smaller and held in reserve to take care of overflow demand. The usual practice at present is to run a definite number of machines of fixed size, and the schedule has not been subject to alteration in emergencies except on reasonably long notice. Passages must therefore be engaged well in advance to make sure of securing them.

The system works passably well where the business is largely with tourists, but it will not prove permanently satisfactory for business men. A service ample for emergency requirements must be provided, and for similar reasons the desire to use large machines must not lead to an undue increase of the intervals between trips. One of the fundamental advantages of airplane transport is that, running relatively small units as it does, it can be operated at much shorter intervals than can a limited-train service, and this advantage must not be sacrificed. It can be laid down as a general rule that, on a popular service, the spacing of departures should be about 30 min. for every 100 miles of length of route. The size of machine used should not be increased beyond six or eight-passenger capacity until that frequency of service has been attained, but thereafter any additional requirements of the traffic should be taken care of by increasing the size of the unit. When we have a route on which there is a steady traffic four or five times as large as that which now exists between London and Paris there will be justification for the use of airplanes carrying 30 to 40 passengers each, and they are sure to come. Already, in his report to the French Chamber of Deputies on the current aeronautical budget, M. Bouilloux-Laffont has considered seriously the possibility of bringing into service airplanes carrying 90 passengers each and has given some estimated figures on the probable operating costs of such a giant, showing much lower unit-cost than any present type. The 90-passenger airplane is not by any means at hand at present, but the trend of progress is distinctly in that direction.

Safety

Safety is dependent chiefly on reliability, structural strength, stability and control, fire prevention and the measures taken to reduce the risk of injury to the passengers if a crash should occur. Reliability has already been mentioned. It becomes of increasing importance, from the safety point of view, with increasing ruggedness of the country flown over and with increasing landing-speed of the airplanes. A high landing speed makes it possible to obtain high speed without an unreasonable sacrifice of economy, but it necessarily increases the danger in a forced landing. The only possibility of using really high wing-loadings, where a single powerplant is used or where in general the design is such that sudden forced landings need be considered, arises through the application of some variable-lift device. It is in connection with commercial aircraft, flying over level country, where high speed at an economical angle of attack is desirable and where great climbing ability is not required, that such mechanisms as flap gears and slotted wings are likely to find their greatest usefulness. The total avoidance of forced landings is possible only by the use of multiple powerplants. At least three distinct units must be used to score a real advance in safety. The independence of the units must, of course, be absolutely complete, extending to fuel, cooling and lubrication systems. There is no excuse in present design for the stoppage of one engine to have an effect on any other.

It is not necessary to take up in detail all of the points that contribute to safety, but there are a few which should be emphasized. To prevent fire, either in the air or after striking the ground with violence, the fixtures of the cabin should be made non-inflammable so far as possible, and the gasoline tanks should be supported under the wings or in some other location well away from the powerplant and the passengers. It is practically impossible always to prevent smoking in the airplane, and with the possibility that a match may be lighted at any time by some thoughtless passenger it is hardly necessary to stress the necessity of eliminating gasoline fumes and lace curtains from inside the fuselage. The question of structural strength need not be dwelt upon, for it goes without saying that structural strength should in all cases be sufficient to provide absolute insurance against failure in the air. The methods of calculation now employed are ample to assure safety under the conditions of utilization of commercial aircraft, whatever difficulties may arise in connection with certain machines traveling at very high speed and being violently maneuvered. The only doubtful point at present is the magnitude of the loads to be allowed for, and even these have become fairly well standardized, although it is my belief that fuselages and rear wing-trusses in commercial machines are in general much stronger than the front trusses of the wing cell and are therefore stronger than they need be.

Stability and control, treated as elements contributing to safety, have attracted too little attention in the past. A large proportion of all accidents result from defects in those features, and particularly from the liability of airplanes to fall into a spin when turning with insufficient power. There may be some objection to classing this as a defect, since spinning is an important factor in the maneuvering of military aircraft, but it is certainly de-

sirable that commercial machines should be spin-proof, and if that aim cannot be attained they should at least be free from the danger of falling into a spin without the pilot's desiring it and substantially without warning. The subject of stability is, of course, too involved to bring into a general report of this kind, but I firmly believe in designing commercial aircraft for a very high degree of longitudinal stability, even at the cost of some sacrifice in readiness of response to the control. These machines are not built to be stunted, and indeed they are not strong enough to stand it. There is no necessity for sudden changes of attitude and there is much to be said for designing so that sudden changes of attitude will become impossible. It is not even necessary in the commercial airplane to change the speed of flight or the angle of attack except at long intervals or for very short periods while climbing or descending, and the airplane should therefore be designed and adjusted to trim at the one particular speed of normal cruising and should resist vigorously any attempt on the part of the pilot to make it depart from that normal condition.

Finally, at least so far as safety is concerned, we have always to consider the possibility of a crash and to minimize its evil results. To do that is largely a matter of the proper relative placing of the component parts of the airplane, arranging them so that as much of the structure as possible will break up before the passengers strike the ground in a bad accident, and so that no heavy weight can fall on the passengers or crew. There are two possible methods of accomplishing this, the first being to place the heavy concentrated loads so that they will strike the ground first as the airplane structure begins to break up and will absorb a large part of the energy of shock in so doing. That is the theory of the conventional tractor machine, and experience has indicated it to be the soundest arrangement yet brought forward. Certainly there is no place in passenger-transport service for the pusher machine with the engine behind the passengers. There should be no place, either, notwithstanding the remarkably fine view which they afford, for those multi-engined types in which some of the passengers are in the extreme nose of the fuselage; or even for the arrangement of a tractor machine, now employed on several commercial types, with the passengers directly behind the engine and the pilot at the rear of the cabin. It is the first duty of a designer to guard the safety of the passengers, even as it is the first duty of the pilot to protect those entrusted to his care, and the structure should be arranged so as to give them the maximum of safety.

Since 19 crashes out of 20 take the major part of the impact on the nose of the fuselage, the obvious requirement for safety is that the passengers shall be placed as far back from the nose as possible. The placing of the pilot near the front of the fuselage also improves his field of vision in those regions most important for a commercial machine, forward and downward. Percentages of blind area do not tell the whole story of effective vision by any means. The pilot of a commercial airplane does not need to watch out for attack from the rear, but there should be as little interference as possible with his view in the directions where danger of collision arises. The second theory of design for safety in crashes has as its basis the placing of the crew or some of the passengers in such a position that they will be shielded by some element of the airplane structure when striking the ground. Notable illustrations are found in certain designs where the pilot is placed beside the engine. Although the scheme is one that has worked very well in some particular embodiments it cannot be considered as generally efficacious for safety as the standard tractor arrangement.

[2] See THE JOURNAL, June, 1922, p. 469.

Speed and Comfort

The steps that must be taken to secure speed have already been suggested. I have shown, in a paper entitled Airplane Performance Formulas,[2] that the speed is governed almost solely by the ratio of the wing loading to the power loading. An increase in the speed therefore means either an increase in the wing loading, with a resultant rise in the landing speed and a loss of climbing power, both of which mean decreased safety, or a decreased power loading, which carries with it a direct and inevitable loss of economic efficiency as measured by pay load per horsepower. The result is, as already noted in the introductory paragraphs, that speed will always be kept as low as possible without loss of business to competing transportation enterprises operating on the ground or water. Over the water, operating speed can be cut as low as 70 m.p.h.

Comfort, the fourth and last of the general qualities to be sought, calls with particular force for discussion by writers, for it has unfortunately suffered from neglect by the designers of commercial aircraft as a whole. Comfort in its broadest sense means good seating arrangements, good ventilation and heating if weather conditions require it, satisfactory vision from the cabin and reasonable freedom from noise. Concerning the seating arrangements, it is necessary only to give warning against excessive crowding of the seats and against the use of chairs turned so that the passengers will be facing backward. Air transport must appeal to the ordinary traveler. A fair percentage of such travelers object to riding backward in a train and the sensation is far more unpleasant in an airplane, particularly when diving for a landing.

The problem of ventilation has not been solved at present. When operating in warm weather, it is comparatively easy to secure satisfactory results simply by providing windows that can be opened although, even then, some care in their placing is necessary in order that the opening of a window may not start a gale blowing through the cabin. The windows should always slide and not swing, and it is advisable to have ventilating panels in the top and bottom of the cabin, in addition to the side windows, so that a current of air of any reasonable velocity that may be desired can be forced through and downward to carry off the vitiated air that hangs near the floor. When an airplane is to be operated through the cold weather, the problem becomes much more acute and has not really been solved to date except by the expedient, in itself a confession of failure of the design, of furnishing Arctic clothing to the passengers. There should be no serious difficulty in heating the cabin from a stove on the exhaust, mixing the air taken in across the hot exhaust-pipe and that taken in from the free atmosphere in proportions controllable by the passengers, but if this is done it is necessary to connect the stove on a portion of the exhaust pipe which is perfectly seamless. The major cause of the bitter complaints against the ventilation of the cabin in some airplanes has been the penetration of small amounts of exhaust fumes to the interior.

Elimination of Noise

While on the subject of exhaust disposal and exhaust heating, something may be said of the silencing difficulty, for the exhaust is the principal factor in noise production. While it is perfectly true, as often suggested, that

if the exhaust were eliminated the propeller would still make considerable noise, particularly with high-speed engines, with the propeller directly mounted on the crankshaft, this is no reason for not trying to suppress the exhaust noise. If that is eliminated what remains will be much less unpleasant to the ears of the passengers than was the original sound.

The reduction of noise is not a matter of great difficulty, far though we are from complete silencing. It is only necessary to use a long exhaust-pipe of ample section, preferably somewhat restricted at the end and discharging well behind the passenger compartment, to reduce the noise to a point where conversation during flight becomes practicable. Having taken that step, the only other acoustic precaution that need be emphasized is the necessity of avoiding any vibration of the structure itself or any sounding-board action of the cabin walls, and particularly of the front wall between the cabin and the powerplant. From the standpoint of reduction of high-frequency structural-vibration and so of noise, it is essential that the usual unsupported panels of sheet metal and veneer be reduced to a minimum. Where flat fireproof bulkheads are desired close to the powerplant, they should be made of asbestos in preference to metal. The use of asbestos or other fibrous and non-resilient materials of somewhat lighter weight, such as felt or kapok fiber, has great possibilities for the deadening of sound in the whole airplane, and the designer of a commercial aircraft should give careful attention to the possibility of backing up walls of plywood or light metal with felt or similar padding. It would hardly be possible to build a truly soundproof cabin, but there is nothing prohibitive in the use of a design or a method of construction which will greatly reduce the noise penetrating into the cabin in other ways than through the open windows.

As already noted, comfort can be liberally interpreted to include vision for the passengers, and this depends in part on the window provision and in part on the general layout of the airplane. It is not difficult to secure reasonably satisfactory vision, but the view for several passengers is much interfered with by the wings in the case of a biplane, or of a monoplane with the wing on the bottom of the fuselage. In this respect the parasol monoplane has a tremendous advantage which alone may prove a decisive factor in favor of its use in some cases, particularly when flying over a country of novel and striking topography, such as the Netherlands or the Florida Keys. One of the great attractions of air transport is the excellence of the view obtained of the country over which one flies, and the designer should plan to press that advantage to the limit.

HAND-WORK

CAREFUL observation extending over a considerable period confirms rather than otherwise the opinion that in the average engineering workshop there are still too many hand-fitting or rectifying operations. Obviously, in connection with some classes of work a certain amount of handwork is unavoidable, as, for example, in the toolroom, particularly in the making of punches and dies. Even on work of this character, however, the provision of a small filing-machine will considerably reduce the amount of actual handwork required.

In some establishments it is still common practice to mark out castings for jigs and fixtures before milling and boring. This procedure in the vast majority of cases is entirely unnecessary, particularly if discretion and care are exercised in dimensioning the tool drawings so that the milling or boring-machine operator may readily utilize the graduated table-feed dials for setting purposes. A further example of toolroom work, where hand methods might advantageously be superseded by machine work, is to be found in connection with the making of milling cutters, broaches and similar appliances. More particularly in the smaller shops it is by no means uncommon to notice bench-hands spending endless hours filing the relief and rake on the cutting teeth of tools such as those mentioned. Judicious use of the relieving lathe and grinding machine would eliminate fully 75 per cent of this tedious and expensive hand-labor.

Flat-form tools are a further item upon which much time is wasted in most establishments. In this connection it may be taken as a definite fact that by far the greater proportion of flat-form tools, required for any class of engineering production, may be completely finished by milling and grinding, and hand-work such as filing and stoning may be eliminated. Such a procedure, of course, necessitates skilled operators, especially as regards grinding, and here again the drafting room can render valuable assistance by the intelligent dimensioning of drawings.

Regarding ordinary production methods there are innumerable instances in practically every plant where the costs are considerably in excess of what they might be, on account of the employment of an excessive amount of hand labor. The "ritual" of scraping-in crankshaft and connecting-rod bearings is to be noticed in practically every establishment, and absorbs many hours of what is, as a general rule, expensive labor. It is very doubtful whether any scraping-in is necessary. One of the best-known automobile companies in America dispenses with this practice entirely, and after the preliminary machining of the bearings, merely tightens the bearing caps to the desired extent while the engine is being run-in, care being taken to make sure that the bearings under treatment are flooded with oil, to act as both a coolant and a lubricant. If, however, a certain amount of scraping is deemed essential, the operation can be considerably reduced as regards time and expense if the bearings in both the crankcase and the connecting-rod are broached practically to size before the scraping process is commenced.

In many plants it is still the practice first to mill the flat faces, and the flat or the semi-circular ends of the crankshaft webs, and then finish these surfaces by hand-filing. By employing a grinding machine in conjunction with a special form or cam-controlled attachment both the semi-circular or the flat ends, together with the flat sides of the webs, can be finish-ground at one setting, and the time taken is about one-fifth of that required for hand-filing.

Hand-fitting or finishing is undoubtedly the most expensive manufacturing process of all, and in addition to high costs, work produced by hand cannot possibly be on the same interchangeable basis as that produced by machine methods.—*Engineering Production* (London).

Officers of the Society

At the Annual Meeting of the Society held last month, a President; a First Vice-President; five Second Vice-Presidents and four Councilors, three of whom were chosen for the full term of 2 years and one to serve for 1 year only, were elected; and the Treasurer was reelected. In addition to these officers two of the three Councilors elected at the 1922 Annual Meeting and the last Past-President are voting members of the Council for 1923. Such photographs of the officers and Councilors as it was possible to secure are presented on the following pages; and their careers are outlined below.

H. W. Alden

President Alden was born at Lynndonville, Vt., Dec. 20, 1870. He received his technical education at the Massachusetts Institute of Technology, being graduated from the mechanical engineering course in 1893. For the next 2 years he was associated with the American Projectile Co., Lynn, Mass., in the capacity of engineer.

His connection with the automotive industry dates back to 1895, when he became associated with the Pope Mfg. Co., Hartford, Conn., as an engineer on experimental work. When the Pope organization subsequently became the Electric Vehicle Co., Mr. Alden retained his position until 1906. At that time he became chief engineer of the Timken Roller Bearing Axle Co., Canton, Ohio, and 3 years later helped to organize the Timken-Detroit Axle Co., being made its chief engineer and moving from Canton to Detroit. In 1914 Mr. Alden was elected vice-president of this company and last December was made chairman of the board of directors.

In June 1917 he was commissioned a major in the Ordnance Department and was detailed to take charge of the development of tanks. In September of that year he sailed for France to study tank warfare and cooperate with the French and English Governments in the development of tanks. After remaining abroad for 4 months he returned to the United States in January, 1918, to supervise the engineering work of the program that had been worked out abroad. In February of the following year he was discharged from the service and in July, 1919, received the Distinguished Service Medal for representing the United States Government in France and England on tank matters and for the development of new tank-designs.

Mr. Alden was elected to Member grade in the Society on March 15, 1905, and, following the death of the late Henry F. Donaldson in 1912, served as President of the Society for the latter half of that year. He is also a member of the Ordnance Advisory Committee of the Society. He was elected to membership in the American Society of Mechanical Engineers in 1908.

Henry M. Crane

First Vice-President Crane was born on June 16, 1874. He received his education in private schools, with a final year at Phillips Exeter Academy, being graduated in 1891. He was graduated from Massachusetts Institute of Technology in 1895 with the degree of Bachelor of Science in Mechanical Engineering and in 1896 with a similar degree in Electrical Engineering.

After graduating he joined the laboratory force of the American Telephone & Telegraph Co. in Boston and worked there 2 years. In 1898 he was transferred to the engineering department of the Western Electric Co. in New York City, where he worked first on the preparation of telephone switchboard installation specifications and later on the development of apparatus and circuits. In 1905 he left the engineering department to become engineering assistant to H. B. Thayer, general manager of the company, and the following year resigned from the company.

In 1906 Mr. Crane organized the Crane & Whitman Co. in Bayonne, N. J., for the development of gasoline automotive machinery and especially motor cars. This company later became the Crane Motor Car Co., and in 1914 was consolidated with the Simplex Automobile Co. He was president of the Crane Motor Car Co. and vice-president of the Simplex Automobile Co.

In 1916 the Wright-Martin Co. was organized and absorbed the Simplex company. Mr. Crane became vice-president in charge of engineering and remained in this position after the reorganization of the company as the Wright Aeronautical Corporation, about Jan. 1, 1920. He resigned from the latter company in March 1920, and for the remainder of the year was not engaged in any regular business but did some consulting work. During the past year he has been engaged in the development of a new passenger car.

Mr. Crane has taken a prominent part in the work of the Fuel Committee of the Society, and is Chairman of its Research Committee and the Aeronautical Division of the Standards Committee. At the 1920 Annual Meeting of the Society he was elected Second Vice-President representing aeronautic engineering, and was elected a Councilor at the 1922 Annual Meeting of the Society.

A. W. Scarratt

Second Vice-President Scarratt, representing tractor engineering, was born in St. Paul, Minn., April 16, 1886. He received his early education in the public schools there. Later he was graduated from the Mechanic Arts High School of St. Paul after completing the engineering course. In 1905 he was employed by the Twin City Rapid Transit Co. as a draftsman in the mechanical engineering department, where he was engaged in the design of car bodies and rolling stock of all kinds for approximately 4½ years. He was then transferred to the power and electrical department, where his work consisted of powerhouse layouts and reconstruction work and sub-station design; and was later made assistant foreman at the shops of the company. While with this company he attended the University of Minnesota for 3 years.

In 1913 Mr. Scarratt accepted a position in the tractor engineering department of the Minneapolis Steel & Machinery Co. He has been prominently identified with the development and production of the line of tractors built by this company.

He was elected to membership in the Society in 1915 and was vice-chairman of the Minneapolis Section in 1920. He was elected a Councilor in 1920.

A. F. Masury

Second Vice-President Masury, representing motor-car engineering, was born at Danvers, Mass., in 1882. He was graduated from Brown University in 1904 with the degree of Mechanical Engineer, and became associated with the General Electric Co. at its Lynn, Mass.,

H. W. ALDEN

plant in the building of heavy-duty electrical machinery. The following year marked the beginning of Mr. Masury's connection with the automotive industry, as at that time he was retained as engineer by the Vaughn Machine Co., Peabody, Mass., which was engaged in the development of two radically different motor-vehicles, the Gaselec passenger-car which had a magnetic clutch, and a steam motor-truck modeled along the lines of the Coulthard vehicle that was being built in England at that time.

In 1907 Mr. Masury became shop foreman and engineering assistant for the Hewitt Motor Co., which at that time was building 10-ton trucks in New York City. He was subsequently sent to Brooklyn to superintend the construction at a plant there and was made assistant chief engineer of the company in 1908. When the International Motor Co. was formed by the consolidation of the Hewitt Motor Co., the Mack Bros. Motor Car Co. and the Saurer Motor Co., Mr. Masury was made New York City service-manager and shortly afterward was engaged in the selling in the New York territory of the trucks built by this organization. In 1912 Mr. Masury was appointed chief engineer of the International Motor Co., and was elected to serve as its third vice-president in 1918.

Mr. Masury was elected to Member Grade in the Society in 1908.

E. P. Warner

Second Vice-President Warner, representing aeronautic engineering, was born in Pittsburgh, on Nov. 9, 1894. He was educated at the Volkmann School, Boston, and after being graduated from Harvard University with the degree of Bachelor of Arts in 1916, attended the Massachusetts Institute of Technology, receiving the degree of Bachelor of Science in 1917 and that of Master of Science in 1919.

During the war he was employed as aeronautical engineer for the Air Service in connection with research and also as instructor in the military course in aeronautical engineering at the Massachusetts Institute of Technology. From January 1919 to June 1920 Mr. Warner served the National Advisory Committee for Aeronautics as chief physicist, directing aeronautical research work at Langley Field; and for 3 months after that time he continued with the Committee as acting technical assistant in Europe. Since the fall of 1920 he has been associate professor of aeronautical engineering at the Massachusetts Institute of Technology.

He was elected to Member grade in the Society in 1917. Professor Warner is also a member of the American Society of Mechanical Engineers, the Society of Naval Architects and Marine Engineers, the American Physical Society, and an associate fellow of the Royal Aeronautical Society. He has been sole or joint author of about 40 published reports and papers, one of which, Airplane Performance Formulas, was presented at the 1922 Semi-Annual Meeting of the Society.

L. W. Witry

Second Vice-President Witry, representing stationary internal-combustion engineering, was born at Waterloo, Iowa, March 28, 1870. In 1884 he became an apprentice in a railroad shop and followed the machinist's trade for 13 years. His experience in that period covered all branches of machine work as it is performed by railroads, including machine and erecting shops, roundhouse work, valve-setting and adjusting airbrakes.

Mr. Witry's connection with the automotive industry dates back to 1897 when he became associated with the Waterloo Gas Engine Co., Waterloo, Iowa, as a machinist. After serving in that capacity for 5 months he was placed in charge of the engineering work and of the factory of the company, subsequently being made a member of the firm and holding the office of vice-president and chief engineer. When the Waterloo company was purchased by Deere & Co. in March 1918, Mr. Witry was continued as vice-president and chief engineer and has held these positions ever since.

Mr. Witry was elected to Member grade in the Society April 17, 1917.

E. J. Hall

Second Vice-President Hall, representing marine engineering, was born at San Jose, Cal., April 30, 1882. He received his education in the night schools of San Francisco and took a steam engineering course in the International Correspondence Schools, becoming a steam engineer in the employ of the irrigation plants in the Santa Clara valley at the age of 16. Subsequently he learned pattern-making, foundry and machine-shop practice in the shops of San Francisco and while in the service of the I. L. Burton Machine Works of that city began the design of marine and hoisting engines and various kinds of gas engine.

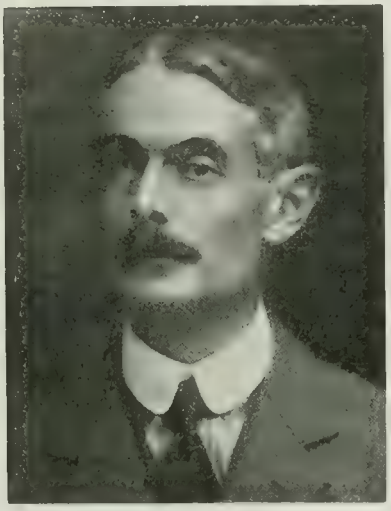
In 1902 Mr. Hall was given a half interest in the Burton company and in the following year began building hill-climbing automobile engines to replace those in the cars being shipped to the Pacific coast. This marks the beginning of his association with the automotive industry, as he then specialized in the production of commercial automobile engines; in 1905 he became associated with the Heine-Velox Co., a builder of complete automobiles. The plants of both this company and the Burton organization were destroyed in the earthquake and fire of 1906 and Mr. Hall took charge of a large mechanical school. In 1907 he became designer and manager for the Comet Automobile Co. Later he opened an independent repair-shop and factory and built a car of his own design which bore the trade name of the Comet. In 1909 he, together with Bruce Kennedy, organized the Hall-Kennedy Works and a year later with B. C. Scott organized the Hall-Scott Motor Car Co. to build industrial locomotives, gasoline-driven railroad coaches, interurban electric-car bodies and automobile and aviation engines. Since the organization of this company Mr. Hall has been first vice-president and factory manager.

In 1913 four and eight-cylinder Hall-Scott aviation engines were flown successfully in America and the company supplied engines to numerous airplane companies that were beginning to spring up all over the Country at that time. Two years later the company designed and perfected a six-cylinder aviation engine which was sold to the Government of the United States and several foreign countries, large numbers being used by the Allies in the European War. Together with Past-President Vincent, Mr. Hall is entitled to the credit for designing the Liberty engine, having been invited in May 1917 by Col. E. A. Deeds of the Aircraft Production Board to collaborate with Mr. Vincent in the design of a new all-American aviation engine. The part played by both of these members in the development of this engine was given in the paper by Mr. Vincent entitled the Liberty Aircraft Engine that was presented at the 1919 Annual Meeting of the Society. Mr. Hall remained in the City of Washington as consulting engineer for the Aircraft Production Board and when the equipment division of the Signal Corps was formed in August 1917 he was

E. J HALL

A. F. MASURY

A. W. SCARRATT



H. M. CRANE

L. W. WITRY

E. P. WARNER

C. B. WHITTELSEY

placed in charge of the production and engineering of the 8- and 12-cylinder Liberty engines and spent several months in organizing eight plants throughout the Country for quantity output.

He was commissioned major in the Signal Corps in October 1917 and in February 1918 was asked to perfect the construction of airplanes and equipment and speed up the production of the DeHaviland and Bristol airplanes which were urgently needed at the fighting front. Major Hall was promoted to the rank of Lieutenant Colonel in April 1918 and went to France the following July as a member of the Lockhart Aviation Mission at the request of General Pershing. After making a complete report of conditions at the front he was appointed chief of the technical section of the Air Service in France on Oct. 17. "For exceptionally meritorious and conspicuous service rendered in the designing of the Liberty engine and subsequently in the adapting of the LeRhone engine to the American methods of production and also in pushing to completion the American adaptation of the DeHaviland plane," Mr. Hall was awarded the Distinguished Service Medal. He was elected to Member grade in the Society on March 14, 1917.

W. A. Chryst

Councilor Chryst was born in Dayton, Ohio, Oct. 21, 1877. His early education was received in the public schools of his birthplace and also in the night schools conducted by the Young Men's Christian Association.

In 1892 he became associated with the National Cash Register Co. and served in various capacities, having charge of one of its inventions departments in 1911, when he became chief engineer of the Dayton Engineering Laboratories Co. Mr. Chryst has been engaged since 1909 in the design of electrical equipment for automotive purposes, including the earliest types of starting, lighting and ignition apparatus developed by the Dayton company.

He was elected to Member Grade in the Society on July 29, 1912. Since January 1917 Mr. Chryst has been a member of the Electrical Equipment Division of the Standards Committee and served as one of the Vice-Chairmen of the Committee in 1921.

F. W. Gurney

Councilor Gurney was born April 21, 1867, at New Braintree, Mass., and was educated at Oberlin College, being graduated therefrom in 1891 with the degree of Bachelor of Arts. After leaving college he invented a machine for turning out wooden bowls which were and are still being manufactured by the Gurney Mfg. Co. in the South. Shortly after this Mr. Gurney invented a wood split pulley that was also produced by this company.

His connection with the automotive industry dates back to the winter of 1900 when he went to Jamestown, N. Y. The following summer he became interested in ball bearings and in the fall of 1903 organized the Gurney Ball Bearing Co., of which he is chief engineer.

Mr. Gurney was elected to Member grade in the Society Sept. 10, 1917.

A. J. Scaife

Councilor Scaife was born in England in 1875 and 5 years later came to America and settled with his family at Cleveland. His early education was received in the grammar and high schools in the vicinity of Cleveland. In 1895 Mr. Scaife's business career began as an apprentice in the toolroom of the A. L. Moore Co., Cleveland. In the fall of 1897 he attended college and the following summer returned to the toolroom of the stamping department of the Cleveland Machine Screw Co., which had succeeded the Moore organization.

In the fall of 1899 he was employed by the Parish & Bingham Co., Cleveland, as a toolmaker and in November of the following year entered the service of the White Sewing Machine Co. as a toolmaker in its automobile department. In the spring of 1901 Mr. Scaife was transferred to the testing department and later to the drawing-room and experimental department where he remained until 1907 when the name of the organization was changed to the White Co. For the next 7 years he was employed in the engineering department of the White Co., having charge of the testing and carbureter departments and also doing some development work. From 1918 to 1921 Mr. Scaife was consulting engineer for the White Motor Co., which was organized in 1914 to succeed the White Co. Since the fall of 1921 he has been factory service engineer in charge of field service for this company.

Mr. Scaife was elected an Associate of the Society on Dec. 23, 1910, and was transferred to Member grade Oct. 1, 1911. He served as a member of the Truck Division of the Standards Committee from 1918 to 1921 inclusive and was Vice-Chairman of the Division last year. When the Cleveland Section was organized in 1915 Mr. Scaife was elected its first treasurer and was chairman of the Section for the year 1916-1917.

H. M. Swetland

Councilor Swetland, who is also the first charter member of the Society, was born in Erie County, Pa., Nov. 15, 1853. The following year his parents moved to western New York where he received his education in the village school and subsequently taught the schools of small villages for 10 years, beginning in 1871.

In 1881 Mr. Swetland entered the publishing business and 3 years later became interested in the steam-engineering journal, *Power*. A few years later he became proprietor of this periodical which he published until its sale to John Hill in 1902. At that time he entered the publishing field of the automotive industry. He founded and established *The Automobile*, now *Automotive Industries;* and promoted *Motor Age, Motor World, The Commercial Vehicle*, and other publications in the automotive field.

Mr. Swetland was the first to foresee the necessity of cooperation among the engineers in the automotive field and through his individual efforts the Society of Automobile Engineers, as it was known at that time, was founded in 1905. It was due chiefly to his efforts that the Society was promoted to sufficient standing to warrant the selection of an active head and he was one of four to finance the Society through its development period. Since the formation of the Society he has served continuously as Chairman of the Finance Committee.

C. F. Scott

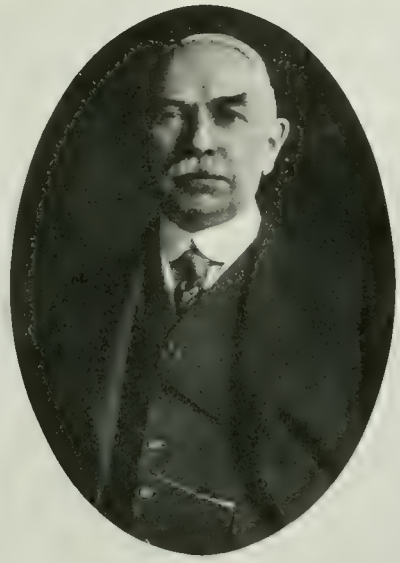
Councilor Scott was born at New York City on May 30, 1886. He prepared for college at the Haverford School, Haverford, Pa., for 4 years, and was graduated from the mechanical-engineering course at Haverford College in 1908.

Following his graduation he entered the service of the Sprague Electric Works in the engineering department. After serving 1 year as a designing engineer he was appointed commercial engineer of electric motor and control applications. He has been identified with the de-

LON R. SMITH

A. J. SCAIFE

C. F. SCOTT



H. M. SWETLAND

B. B. BACHMAN

F. W. GURNEY

W. A. CHRYST

velopment and application of the electric dynamometer almost from its inception in 1909. In connection with his work on dynamometers Mr. Scott specialized for some years in the adapting of the electric dynamometer to testing automobile engines by a thorough study of the internal-combustion engine. He developed and installed the first electric dynamometer for testing a complete automobile chassis. Mr. Scott is now manager of the Sprague Apparatus Products Section of the General Electric Co.

Mr. Scott was elected to Junior grade in the Society Oct. 24, 1911, and was transferred to Member grade Sept. 11, 1912. He was elected Chairman of the Metropolitan Section in 1918 and became Vice-Chairman the following year. He was a member of the Society Nominating Committee, representing the Metropolitan Section, in 1918 and 1919, and was secretary of the Committee in the latter year, and a member at large of the 1920 committee. He has been a member of the Meetings Committee of the Society since 1919 and served as chairman of the Committee in 1921 and 1922.

Lon R. Smith

Councilor Smith was born at Brownsburg, Ind., Dec. 24, 1876. After being graduated from high school, he spent 4 years at pattern-making and 3 more at die-sinking. Since entering the service of the Motsinger Device Mfg. Co., Pendleton, Ind., as superintendent in 1903, Mr. Smith's experience has been confined to the development of ignition, carburetion and engines. In 1907 he became superintendent of the magneto factory of the Henricks Novelty Co., Indianapolis, and from 1908 to 1910 was a salesman for that organization.

In March 1910 he was appointed Western representative of the Eisemann Magneto Co. and as such represented it in all of the United States west of Buffalo with the exception of Michigan and Wisconsin until the fall of 1916. At that time he became sales manager of the engine department of the Buda Co., Harvey, Ill. He left that company in June 1919 to accept the position of vice-president, directing sales and advertising, with the Midwest Engine Co., Indianapolis, resigning in the fall of 1921 when the company was reorganized.

Mr. Smith was elected to Member grade in the Society on June 12, 1911, and was Chairman of the Indiana Section in 1915 and 1916, and was reelected Chairman in the spring of 1921. He was elected Treasurer of the Mid-West Section in 1918 and Vice-Chairman of the Indiana Section in 1922.

B. B. Bachman

Past-President Bachman was born Oct. 4, 1886, educated at grammar school, night school and under a private tutor, and started his business experience in 1900 as a tracer. The next 10 years were spent as tracer, detailer and designer with the Enterprise Mfg. Co., and the Falkenay Sinclair Machine Tool Co., both of Philadelphia, and the Autocar Co., Ardmore, Pa. His entire automobile experience has been with the last-named company, which was a builder of passenger vehicles until 1912 and has constructed commercial vehicles from 1907 to date. Starting with this company in February 1905, he became assistant engineer in 1909 and engineer in 1914.

Mr. Bachman was elected a Junior member of the Society in 1910 and transferred to Member grade in 1912. He is a member of the American Society of Mechanical Engineers, American Society for Testing Materials and the Institution of Automobile Engineers. When the Pennsylvania Section was organized he was one of the charter members and served as its first secretary. He was identified with the work of the Truck Standards Division in 1911 and was Chairman of the Standards Committee from 1918 to 1922. At present he is a representative of the Society on the American Engineering Standards Committee. He was elected to the Council in 1916 and again in 1918. In 1919 he was First Vice-President of the Society, and in 1921 Second Vice-President representing motor-car engineering. As a member of the Truck Standards Division Mr. Bachman participated in the formulation of the specifications for military trucks for the Quartermaster Department, and afterwards was engaged at irregular intervals in the design of Class B and Class A military trucks. In connection with the last named, he was chairman of the committee on design.

At the 1913 Annual Meeting Mr. Bachman presented a paper entitled Comparative Results with Solid and Pneumatic Tires on Light Commercial Vehicles, and at the 1914 Annual Meeting he treated the subject of Double-Reduction Live Axle. At the 1919 Motor Truck Meeting he gave an address on Pneumatic Tires for Trucks.

Charles B. Whittelsey

Treasurer Whittelsey has been connected with the Hartford Rubber Works Co. since 1901, beginning as its purchasing agent. In 1905 he was made assistant to the general manager, in 1906 superintendent, in 1911 secretary and factory manager, in 1915 vice-president and factory manager, and in 1916 president and factory manager. He has served as president of the Hartford Chamber of Commerce and of the Hartford County Manufacturers' Association.

Mr. Whittelsey was elected to Member grade in the Society in 1910. In 1916 he was elected a Life Member. He was a member of the Standards Committee for several years, beginning in 1911, and served as chairman of the Tire and Rim Division in 1918 and 1919. Mr. Whittelsey was a member of the Council in 1912 and 1913, and was elected Treasurer in 1918 and reelected each year since. At the 1912 Annual Meeting he delivered a paper on Solid Motor Tires, and at the 1915 Annual Meeting presented a paper entitled the Pros and Cons of Tire Inflation.

C. F. Clarkson

Secretary and General Manager Clarkson was born at Des Moines, Iowa, in 1870, and was graduated from Phillips Exeter Academy in 1888. In 1889 he was in Government service in the Post Office Department. He was graduated from Harvard College in 1894, pursuing post-graduate work there for the next 2 years. He was next engaged in connection with the installation of an underground telephone system in Philadelphia for 2 years, after which time he moved to New York City and spent several years in work on technical, legal, patent, laboratory and automobile subjects. From 1905 to 1910 he was connected with the Association of Licensed Automobile Manufacturers, as secretary of its Mechanical Branch, publicity manager and assistant general manager. During this time he was the editor of the A.L.A.M. Mechanical Branch Bulletins and of the A.L.A.M. weekly digest of current technical literature.

Mr. Clarkson has been Secretary and General Manager of the Society of Automobile Engineers and of the Society of Automotive Engineers since 1910.

During the war Mr. Clarkson was associated with the Council of National Defense, and served as a member of the automotive products section of the War Industries Board and of the International Aircraft Standards Board.

Presidential Address of B. B. Bachman

IT has become, through custom, a duty for your president to give you at the Annual Meeting an account of his stewardship for the year. In many respects, this is a most difficult task. The opportunities for constructive effort are legion but, unfortunately, one cannot help but feel, when a backward view is taken, that most of them were allowed to pass by unnoticed. Viewed from the beginning, a year seems a reasonably long time; but in retrospect it seems like the "tale that is told."

The purpose of the Society, as outlined in the Constitution, "is to promote the Arts and Sciences connected with Engineering and Mechanical Construction of Automotive Apparatus." There are apparently many ways in which this purpose can be furthered, but for one reason or another many of them fail in practical application, although they are theoretically most attractive and promising. It is a sad commentary on the vaunted mental capacity of humanity that progress is almost entirely a process of trial and error, and only to a very limited degree the result of thorough analysis.

Society Meetings

Recognizing this fact and realizing that individual experience varies, as well as the analysis of experience and the interpretation of results, it can be accepted that one of the most effective ways in which we can further our object is to provide for meetings in which experience can be related, facts reported, theories advanced and, by discussion and criticism, errors in deduction pointed out and stimulus given for renewed effort. It seems to me that such a conception indicates that a large part of the benefit to be obtained is through the reaction of the group on the individual. It is my belief that these facts are not so generally appreciated as they should be, and it is for this reason that a greater attendance at and participation in meetings are difficult to attain. At the same time, we must not lose sight of the fact that there is such a multiplicity of meetings that it becomes exceedingly difficult at times to decide which should be attended and which may safely be let go.

The meetings held during the year, including the meetings of the Sections, have been most diversified as to topics and cannot have failed to contain something of value and interest to anyone connected with the industry. In spite of all this, there seems to be a peculiar apathy on the part of many that results in a small attendance at and a limited participation in these meetings. The lack of support on the part of those most intimately connected with the engineering side of the industry has been the cause for much concern to the Meetings Committee and the Council.

For some years, there has been talk of holding the Annual Meeting in the Middle West on the ground that it is more central for the large proportion of the members. It is, of course, necessary to hold at least the business meeting in the State of New York, but it is possible that it might be well to have only a single-day's session here and then hold sessions at a later date in one of our Western cities. The Meetings Committee has also advanced the thought that an additional meeting in the spring, to be held in the West, would be in keeping with the essential expansion of activities and afford an opportunity for discussion that, by reason of the lack of time, cannot be provided for in either our Annual or Summer Meetings. This is especially true, since the Summer Meeting in recent years has come to be devoted to a considerable extent to recreation. This fact has become the subject of adverse comment and criticism that, I think, is, in large part, unfounded. It is to be regretted, however, that we do not have engineers participate in these meetings to a greater degree. The fact that technical sessions do not fill the entire time is no indication of the possible benefit to be derived. There are few, if any, other opportunities during the year to get together for private discussion and exchange of experience. It is a mistaken conception that the value of a meeting is to be measured by the number of papers with titles breathing importance and text bristling with mathematical symbols.

Engineering is a vocation that has suffered too long from ingrowing thought. We need to develop our capacity for knowing each other and our fellow men so that we may bring to our work a knowledge of a broader thought than that which has to do with technicality alone.

Production Session

A year ago, when I looked forward to the work of 1922 and looked back on the records of my predecessors, I was hopeful that this administrative year would contain some landmark that would distinguish it. I am therefore very proud that, in addition to the general high character of the meetings of the year, it should have been during the year 1922 that the first Production Session of the Society was held. This pride is not personal, but is a satisfaction felt in the accomplishment of the chairman and members of our Meetings Committee, assisted by several of our members in Detroit, who conceived this idea, and developed and carried it to such an eminently satisfactory conclusion. The results of that meeting were such as to stimulate activity and the thought of conducting more meetings of this character in the future.

There is, however, one idea which arose as an outgrowth of this meeting that it will be well for all of us to stop and consider seriously. What I have reference to is the thought that the success of this meeting indicates the need for a production engineers' section. While there are many sound arguments in support of this proposition, I wish to submit for your consideration the view that division in our work as a society may be undesirable. This organization was originally the Society of Automobile Engineers, and when this title was changed to the Society of Automotive Engineers, it was not with the idea of producing a confederation of groups of individuals, but to provide a union in which engineers engaged in the arts and industries founded on the internal-combustion engine could cooperate. Has this union as yet been completed? Is it not true that the truck engineer scans our programs and, if he does not see titles that he conceives to be of direct interest in his labors, refuses to attend particular meetings? The same is true of the engineer engaged in aviation, marine engineering or any of the other classifications. I am convinced in my own mind that we should do everything in our power to eliminate this idea of classification. We are all suffering from the handicap of a limited horizon and it is one of the prime functions of an organization such as ours to furnish a greater breadth of perspective. This cannot be accomplished by individualistic effort.

The success attending the Production Meeting arouses

in my mind the hope that we shall in some way find the means to bring the meetings dealing with the problems of service onto the same plane. Here again is a field in which the engineer is most interested, whether his immediate activities be along the lines of design, production, sales or service. It is my hope that it will be possible to organize such meetings as definitely to convince individuals engaged in all of these lines that they cannot afford to miss them.

The Sections

While it is unnecessary to emphasize the value to the Society resulting from the activities of the Sections, nevertheless the proper organization and regulation of the Sections to insure the obtaining of the greatest good to the greatest number has been from the beginning and continues to be a most vexing problem in many respects. The present healthy condition of the Sections and the valuable contribution they have made to the Society's work is a tribute to the loyalty and devotion, as well as the hard work, which the Sections Officers and Sections Committee have given.

The question of financing the Sections to permit their reasonable growth and furnishing those services to the local membership of the Society that are desirable is most difficult. Up to this time, it has been impossible to reach an agreement that complete support of the Sections' activities should come from the Society funds, although this viewpoint has been presented most earnestly by several of our Sections officers. While I appreciate the force of the arguments that have been advanced in favor of this idea, I am fearful that the adoption of such a policy, attended, as it most probably would be, with a more strict supervision of the Sections' work by the officers or the headquarters staff of the Society, would result only in an undesirable restriction of the initiative of the local organizations which would inevitably affect their efficiency adversely.

In short, it is my belief that the Sections should be given the largest amount of freedom possible in the conduct of their affairs. This freedom of action, of course, carries with it certain responsibilities and obligations which, if accepted and faced, will result in a stronger and more effective organization than one that is fostered and supervised more closely by the Society.

Society Membership

During the past year, as I reported to you at the Summer Meeting, we have been faced with the matter of a considerable number of resignations, together with the necessity of dropping a number of members due to nonpayment of dues. While it might be considered that this condition, in large part, was due to the unsettled industrial conditions, with the consequent inability of a number to keep up their membership, it was felt that it was worthy of considerable study to determine whether by any chance a misunderstanding on the part of the individual as to the value of the Society's work or a lack of proper service on the part of the Society to the individual might be responsible.

To investigate this matter, Past-President Beecroft was appointed chairman and given authority to organize a committee. As a result of their study and recommendation a large number of names have been eliminated from our rolls by resignation and removal, which number approximately balances the new members received and leaves the total membership of the Society at this time about where it was a year ago.

While this loss is regrettable, the total showing, in view of the conditions we have faced, is not altogether discouraging. During the past 5 years we have passed through a period when many men entered the industry or allied lines through war work and joined the Society. The subsequent contraction affected many and made it necessary for them to go into other fields where they no longer felt an interest in our activities or could not be benefited by them. This condition seems to have been inevitable and natural, and largely explains the membership losses mentioned.

From the standpoint of numbers and the representative character, the membership of the Society is most satisfactory. If the time ever existed, it has passed, when we had to approach prospective members on the basis of our need of them. The development of the organization has produced a variety of services and a fund of experience in doing things that will provide something of value to any man, and it is time we all recognize this fact and proceed to act accordingly. Recognizing this, we must still realize that there are many men who should be members, and that not in name only, but in a most active capacity. Reference has already been made to the production engineer and the service engineer; both should be more prominent in our membership. We could afford to spend much more time than we do in considering so-called production and service problems. I have never been able to understand the opinion that separates these factors from the field of engineering. Rather, it is to be regretted that we do not have abler discussions of phases of these subjects that are presented to us from time to time.

Classification of Members

In connection with the matter of membership, there is one consideration that I believe merits careful thought. At the business session in June we had considerable discussion on the subject of classification in Member and Associate grades. While I believe in the essential soundness of the policy which recognizes that a difference in qualifications, based upon training, experience and occupation, coupled with an active interest in the aims of the Society, can be provided for most suitably by a division of the membership into classes. I am not certain that the present method of classification is the best possible. Furthermore, I am inclined to feel that, while this is an organization of engineers, and as such should be controlled and managed by and for engineers, it may be wise to stop and consider what in future will be the problems arising out of a large body of members with no voice in the affairs of the Society.

Time was when the Associate had equal power of suffrage with the Member, and modification of the constitutions of several of our sister societies has instituted this feature recently. Whether such a step is wise, is at least open to question, but the fact remains that the situation calls for study and careful consideration.

Research

The work of the Research Department has gone forward in a most satisfactory way, and the Committee and the Manager are to be congratulated on the manner in which the foundations of this work have been laid. Undoubtedly, you have all noticed in recent months the contributions to The Journal which have been made by the department; these should become of greater and greater value as time goes on and the work becomes more firmly established.

One very gratifying result of the activity of the Research Department has been the cooperative investiga-

tion, under the auspices of the American Petroleum Institute, the National Automobile Chamber of Commerce and the Society, conducted by the Bureau of Standards in the matter of determining the effect that a variation in volatility of fuel has on its general usefulness in existing types of motor vehicles. Some of the results of this work have been published, and more of them will be outlined during this meeting. The data reported should go far toward giving the representatives of the petroleum and the automotive industries a basis for discussion.

A valuable by-product of this work has been the broader viewpoint and more general familiarity of the other fellow's problem that the association of representatives of the two industries has developed.

Finances

With regard to the financial condition of the Society, I feel that the report of the Treasurer can be considered most satisfactory. It is, of course, to be regretted that conditions were such as to make a deficit in the operating account unavoidable. However, it is gratifying that the anticipated deficit which we faced at the beginning of the year, was reduced by approximately one-half at the end of the fiscal year.

The outlook for the new year is most promising. The Finance Committee in estimating the budget has presented to the Council a report, which was accepted, indicating that, without a reduction in the activities of the Society and with only a reasonable increase in revenue from membership and publications, it will be possible to make income and expense balance. In the light of the general industrial conditions during most of the past year, I feel that this condition is highly encouraging.

Finally, I wish to thank you all for the charity with which you have received my efforts during the year, and for the support that has been given by the Council, committees, members and the General Manager and his staff. The duties of the office are becoming difficult and exacting and, while I have appreciated greatly the honor accorded me in selection for the office, and though the work has contained many elements of satisfaction, it is only honest to confess that I am viewing the end of my responsibilities with a feeling of relief.

With this in mind, I want to bespeak for the one you select as my successor the same cordial support which alone has made it at all possible for me to carry-on this year.

SIMPLIFICATION

THE American Engineering Standards Committee has requested assistance in the canvass its cooperating bodies are making at the request of Secretary Hoover, of the Department of Commerce, for suggestions in regard to subjects in which there is a need for industrial simplification through a reduction in the number of styles, sizes and cataloged lines. In the opinion of the American Engineering Standards Committee, engineers and industrialists can render a notable service to American industry by making such an analysis of the needs of industry.

Reference is made to the importance of the economic losses involved in non-standard manufacture and an unnecessary variety of styles, types and sizes of staple materials, products and processes, and suggestions are called for from the standpoint of the members as technical and professional men, whether as producers, designers, consultants, buyers, fabricators or final consumers, or as members of the great body of general consumers. The form given below is provided for this purpose, which it is requested be filled out and mailed to the office of the Society.

The more specific the suggestions are, the more effective they will be in helping to bring about active work on definite projects, and, through this, actual concrete results introduced into the industries.

Subjects for Simplification and Standardization

Inquiry made by the Society of Automotive Engineers, Inc., at the request of Secretary Hoover and the American Engineering Standards Committee

(1) In what raw materials or manufactured products do you believe a reduction in the number of styles, sizes, grades or cataloged lines would bring about economy in purchases, production, distribution or selling?

General Subject .....

Specific Items .....

.....

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General Subject .....

Specific Items .....

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(2) In connection with what subjects or items do you think the Society of Automotive Engineers should take an active part, as an organization, in bringing about such simplification or standardization?

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Signature.....

Business Address.....

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Please include explanations and further suggestions on a separate sheet. Such "background" will be helpful.

Questions Answered by the Research Department

MANY of the inquiries answered by the Research Department are of much general interest and involve a considerable amount of thought and research. For the information of our members a few of them will be published each month. It is hoped that in this way those members who have not yet availed themselves of the facilities offered by the Research Department may be encouraged to take advantage of them in the future.

PISTON-RING CLICK

A LETTER was received from a company handling repairs and replacements, describing some of its experiences with the phenomenon of piston-ring tick or click, stating some observations, and asking for further information on the subject.

Copies of the letter were sent to a number of engineers, with a request for their views. The following extracts from replies received illustrate the divergence of opinion on this question:

My experience with the click in piston-rings is that it is due to their being fitted with too small a gap. Piston-rings, generally speaking, should not be fitted with less than 0.015-in. gap. I believe that, if this amount of gap is used, the click will disappear.

We have had considerable experience with this condition. In every instance, so far as we have been able to determine, the click was caused by insufficient clearance between the ends of the piston-rings.

We have carefully checked-up the matter on brand new cylinder-blocks and pistons, as well as on worn blocks. The same condition will exist in either of these if there is insufficient clearance. Just what is brought about to cause this noise, we are unable to determine definitely, but we have yet to find a case which we have been unable to correct by slightly relieving the ends of the piston-rings.

We believe that this noise is caused by insufficient clearance between the ends of the ring, causing the ends to strike together at the beginning of the firing stroke. In our own experience the noise has usually developed with diagonally cut rings where it is necessary to hold the clearance rather closely.

At various times we have tried filing notches in the upper groove to let the compression in behind the ring, but with a step-cut ring we do not believe that this action is required; we have had no trouble with rings of this type. Our difficulties have not been serious, and for this reason our tests have not been extensive enough to develop any exhaustive conclusions.

We have found that piston-ring tick will occur when the ring bottoms circumferentially at its split, due to being fitted too closely. Excessive over-travel in the cylinder bore can also be expected to give a similar result. These two seem to us to be the most prevalent sources of the condition.

Whatever noises there were in an engine, I have laid to other causes than piston-rings. Of course, worn or poorly fitted rings may cause a click in shifting from one side of the groove to the other, but I believe that correctly fitted rings, with a clearance of, say, not over 0.0005 in., and the clearance cushioned with an oil-film, should remain perfectly silent.

I have experienced piston-ring click on large-bore jobs with rather flexible rings. It was apparently caused by the pressure collapsing the ring until the ends struck. Running the bottom of the groove close to the back of the piston-ring will help the situation. Notching the top of the ring, to let the firing pressure back of the ring, will also relieve the situation, but will make the ring only partly effective as a seal.

I think it is obvious that the trouble develops only where there is considerable clearance between the ends of the ring, as this condition would be necessary to get enough travel to produce the noise. We have never had this trouble where the rings had joint openings just sufficient to take care of expansion, and the groove was not too deep.

In several instances of severe piston-ring click, it was found upon examination that the top ring on the piston projected above the bore of the cylinder at the end of the stroke so that this ring was subjected to the explosion pressure on the outside, thus collapsing the ring and causing an unusually loud click. This trouble was cured by increasing the length of the cylinder bore so that the ring would not project above it, and diminished in some cases by relieving the top face of the ring to allow the explosion pressure to get behind ring and keep it tight against walls of the cylinder.

More frequently, however, this trouble has been encountered in service where the pistons fitted loosely in the cylinders or the cylinders had become tapered, being larger at the top and causing the same effect as loosely fitting pistons. In such cases the piston will rock, causing the oil-film between the ring and the cylinder-wall to be weakest at the top on one side of the piston, so that any appreciable explosion pressure would have a tendency to collapse the ring, in some instances causing a remarkably loud click and even piston slap.

In other cases, the click has been due merely to the ends butting; and is very indistinct. The most notable click, however, is caused by the collapse of the ring. It was found in several instances that the explosion blew-by all of the rings and could be noticed in the crankcase very easily.

Of course, shoulders in cylinders, tapered bores and dry spots due to faulty lubrication can cause piston-ring click. There are, however, cases in which the sound remains after every possible chance of defective installation is removed.

Some time ago we had a great many complaints as to Ford installations on this score. Since then we have increased the radial thickness of our standard Ford-size ring, with the result that the trouble has been entirely eliminated.

The obvious explanation of the sound is that when the pressure rises suddenly in the cylinder the pressure rises both in the oil-film between the ring and the wall and in the space behind the ring. Since the space behind the ring is large compared to that in front of it, and the leakage path into the former space is small, an appreciable time is required for the space in the back of the groove to accumulate the additional gases required for a considerable rise in pressure. On the other hand, the pressure transmission through the thin surface oil-film is practically instantaneous. Therefore, there is a momentary tendency to collapse the ring at

the beginning of every power-stroke. If this differential pressure is great enough to overcome the ring tension, the ring collapses and forces the ends together sharply. Moreover, as the pressure falls, the expansion of the gas behind the ring combines with the ring tension to force the ring violently outward against the cylinder again. The sound results from either or both of these impacts.

According to this theory any method for filling the empty groove-space tends to counteract the trouble, as also does an increase in ring tension. Coasting with the ignition cut off fills the space partially with oil.

We have known of many cases being cured by the insertion of copper filling-strips. The cutting of grooves in the upper edge of the ring fills the space rapidly with gas, thus reducing the pressure-lag; this practice is, of course, not advisable.

This phenomenon of ring click was reproduced on an experimental one-cylinder unit, running the piston against compression only, no explosion, and was cured by

(1) Fitting the piston more neatly to the cylinder

(2) Relieving the top ring to allow pressure to get behind the ring. This was accomplished also by installing rings of thinner face in the top groove, but keeping the clearance in the two lower grooves as small as possible, as would be commercial practice in any service-station

The click was overcome in some instances also by installing rings of greater tension. The clicking of rings was noticed in both step-joint and angle-joint rings, and was overcome in all instances by pinning the rings in the grooves so that the joints did not line-up. It was noticed that clicking was most pronounced when the joints of the rings were approximately in line.

A number of years ago, when this clicking or slapping was brought to our attention, after considerable effort we arrived at a conclusion that we have been unable to disprove.

We have two types of ring installation that will cause this difficulty. One case is where the ring is properly fitted in the groove, but not so well fitted in the cylinder. If the face of the ring is off of the cylinder for a portion of its circumference, the gas pressure reaches the face of the ring and, being more or less checked by the lower rings and the skirt of the piston, causes a contraction of the ring in the groove. If the grooves are filed across the top side of the ring, the pressure reaching the back of the ring seems to offset the pressure on the face of the ring and the clicking stops without any further correction on the face of the ring.

A second case is an installation in which the rings fit perfectly against the cylinder wall but are very tight in the groove; so tight that considerable pressure is required to move them in the groove. We must expect that, while the ring is moving rapidly up and down in the cylinder, there will be a slight movement at least radially in the groove, because the piston clearance and cylinder conditions are never close enough to have the ring remain stationary in the groove. If, then, the ring moves slightly out or in and is pinched tight sideways in the groove, pressure can very easily reach a portion of the face of the ring because the ring is not allowed to "set" out actively in contact with the cylinder. The pressure acts the same as in the first case, driving the ring in; and at the end of the stroke the ring springs back to normal. We have always been able to correct this trouble by removing sufficient metal from the side of the ring to allow it to be free in the groove.

We have tried a number of times, unsuccessfully, to find a connection between the quantity of oil used and this condition. Of course, any projection from the shoulder in the cylinder would cause a noise if the rings were permitted to strike it. But the noise is entirely different from the click or slap experienced in the cases mentioned above.

There is a great tendency to make the fit between the ring and the ring-groove closer. It is very easy to make piston-rings to close limits in good surfaces, but it is a different problem to make piston-ring grooves up to the same standard. We believe that the proper width of ring, together with the proper side-surface on the ring and the groove, will be as effective as a very tightly fitted ring. We think that 0.00075 in. is the limit of tightness in ring-fits in the average commercial job.

SEASONING CAST-IRON PISTONS

Question:—We have been told by some high authorities on the subject that a heat-treatment of piston castings in the rough tends to make them easier to machine and to relieve them of strains so as to keep them from warping after they are finished and put into the job. The method recommended is to let the castings lie in a furnace at 1450 deg. fahr. for about 12 hr. Then, we have been told that seasoning of the rough castings is most beneficial. Still another suggestion is to heat the semi-finished piston to a blue color. Other authorities on the subject have denied both the need and the desirability of any such treatment. Can you give us additional information on this question?

Answer:—In reply to this query we have permission to quote, anonymously, the following opinions of a number of engineers who are specially qualified by experience to discuss this matter.

For practical production work, it has been our practice to heat-treat or anneal the pistons after the roughing cut at as low a temperature as would do, that is, not over 750 deg. fahr. After the annealing, we ground or took a light finishing-cut before grinding. I do not think that this method is as good as aging before the finishing process but it is more practical as a production method.

We have had intermittently considerable experience with the treatment of gray iron for pistons and feel that the highest-grade product is made from castings that have been subjected to a preliminary tumbling process in the foundry cleaning-room and then subjected, for about six weeks, to a yard-seasoning where the castings are exposed to the elements. Such castings are not as easy to machine as those which have been heat-treated from the standpoint of annealing. When time will not permit yard-seasoning, we resort to heat-treatment. We find that the castings cut much more easily, but the metal becomes somewhat lifeless from the standpoint of resilience, and a slight bump or shock of the finished article will cause a permanent set, which is not the case with castings that have been yard-seasoned only. It has been our experience that change of shape in the engine is prevented by sufficient yard-seasoning, as well as by heat-treatment. After all, either method may be used to normalize the iron. We prefer the seasoning process.

It is my opinion that pistons for internal-combustion engines should be heat-treated. In the first place, lightweight pistons must be made of very strong iron which almost approaches steel castings. Inasmuch as the combined carbon depends upon the rate of cooling, and the graphitic carbon being very much less than in ordinary cast iron, piston castings, especially the thin sections, are apt to chill or harden in the mold, making them difficult to machine. For that reason alone, piston castings should be annealed. Furthermore, even with

the most thorough annealing, some internal strains may remain; therefore, for a first-class job, pistons should have an additional treatment between the roughing and the finish-machining processes, in order that they may keep a permanent form after the last finish-grinding.

Our practice is to anneal the pistons prior to machining.

We believe that cylinders warp more than pistons. We therefore do not heat-treat our pistons and cylinders.

The main reason for heat-treating is to relieve the internal strains. Our present method for doing this is as follows: the pistons are first rough-turned, packed in boxes or containers which hold about 12 pieces each, and then placed in a furnace that has been brought to a temperature of 1450 to 1500 deg. fahr. and the heat turned off. The procedure of preheating the furnace we found necessary to eliminate the scale that would otherwise form on the exterior due to flame contact. The pistons are allowed to remain in the furnace from 2 to 2½ hr., after which they are removed and cooled in the air. After this treatment, the pistons present a bluish tint in the way of discoloration. Our old practice on larger sizes was to place the pistons in the furnace as received from the foundry. The heat was then applied and the contents heated to a cherry red, when the flame was turned off and the pistons allowed to cool in the furnace. This was more of an annealing process but we found in some instances that the castings were too soft to conform to our standard.

The United States Bureau of Standards informs us that it has recently started an investigation on a subject related to the heat-treatment of pistons for machining and permanence but that no data are available at the present time. A letter from the Bureau referred to the following five papers on the subject:

C. J. Wiltshire, Elimination of Strains in Castings, *Foundry*, Oct. 1, 1919, p. 684.

L. M. Sherwin, The Effects of Seasoning on Gray-Iron Castings, *Foundry*, October, 1917, p. 435.

J. F. Harper and R. S. MacPherran, The Annealing of Gray-Iron Castings, *The Iron Age*, Oct. 19, 1922, p. 1007.

J. E. Hurst, The Growth of Internal-Combustion Cylinders, *Engineering*, Aug. 4, 1916, p. 97; also The Heat Treatment of Cast Iron at Low Temperatures, *Engineering*, July 4, 1919, p. 1.

These contain the following information on this subject. Wiltshire recommends that

The castings be placed in the oven, the doors closed, the heat turned on, and the temperature raised to 700 deg. fahr., which generally takes from 7 to 8 hr. This temperature is held for an additional 7 hr., when the heat is shut off and the oven allowed to cool down slowly for approximately 20 hr., with a resulting temperature of about 300 deg. fahr. The oven doors are then opened and the temperature is allowed to drop to approximately 150 deg. fahr., when the castings are in shape to be taken out. The entire operation consumes about 48 hr. The ovens are heated with oil and the amount of oil per ton of castings heated has averaged 9.6 gal. Each heat requires 284 gal. of oil. Approximately 29 tons of castings are treated each heat.

Sherwin is interested in finding a treatment of cast iron that will assure its holding its shape permanently after it has been formed into straight-edges, surface-plates and other castings of a similar nature. He finds that for this purpose some sort of seasoning of the castings is beneficial and recommends the second method given below as the most suitable. Among the methods of seasoning practiced by various manufacturers, Sherwin records the following:

(1) The castings remain in one place and position for an indefinite period, in some cases exposed to weather conditions, before being finish-machined

(2) The castings are rough-turned or planed, and then subjected to a heat of several hundred degrees, say as high as 400 deg. fahr., for a definite period of time

(3) The castings are heated from 150 to 300 deg. fahr. before having the scale removed

(4) The castings are heated and reheated several times at 400 deg. fahr.

Sherwin points out that, from what is known about the metallurgy of cast iron, any temperature below the critical point, 1250 deg. fahr., should be satisfactory for relieving strains, and he proves his contention experimentally by showing that test-bars, identical except for the heat-treatment, are indistinguishable as regards tensile-strength and Brinell-hardness and Shore-scleroscope numbers. The bars received the following treatment:

(1) Heated at 400 deg. fahr., for 24 hr.

(2) Heated at 1100 deg. fahr., for 24 hr.

(3) Heated to 1100 deg. fahr., three times, cooled down between each heating

(4) Untreated

Harper and MacPherran made a more extensive investigation of the point raised by Sherwin, namely, "What are the correct time and temperature for heat-treating cast iron to relieve machine and casting strains and to increase machinability?" Their results may be summarized thus:

(1) The rate of cooling has no effect on the physical properties of cast iron so long as the critical temperature is not exceeded

(2) To relieve machine and casting strains, a temperature of 1150 deg. fahr. for 1 hr. should not be exceeded. Continued heating at this temperature is followed by a loss of hardness and strength

(3) Annealing at 1050 deg. fahr. for reasonable periods does not tend to decrease materially the hardness or strength

(4) For increasing machinability, temperatures of from 1450 to 1550 deg. fahr. will be found satisfactory, but in this case the drop in hardness is accompanied by a decided loss of strength

The two papers by Hurst indicate that the situation is not as simple as the three papers just mentioned would lead one to believe. This discrepancy is due to the fact that Hurst discusses the subject from the standpoint of the permanence of the shape of the castings after they have been put into use under conditions where they are subjected to continued or intermittent heating. Under these circumstances, cast iron frequently undergoes a peculiar growth with a consequent increase in volume, a phenomenon that has been known for some time but that is far from being completely understood. Hurst's papers cannot be abstracted here but they are worthy of study, most profitably in connection with chapters 10 to 12 of W. H. Hatfield's book on Cast Iron in the Light of Recent Research, where will be found a readable account of what is known about the effect of temperature on articles made of cast iron.

Gear Grinding

By R. S. Drummond[1]

Detroit Section Paper *Illustrated with* Photographs

THE author discusses only gear-grinding work on gear-teeth subsequent to heat-treatment and pays particular attention to automobile transmission gears. He states that as yet very little is done in the grinding of gear-teeth that have not been heat-treated.

The salvaging of gears that have been rejected and the finish-grinding of gears that have grinding stock remaining upon the teeth are commented upon, together with remarks on the cost of grinding, the history of gear grinding, the different classes of work performed, gear-grinding machines in general, tooth-form and gear wear. It is stated that gear grinding is commercially a production operation having as its aim the placing of the correct tooth-shape and proper surface-finish on gear-teeth so that the gears can move accurately, noiselessly and without wear; and that the cost of finished acceptable transmissions is less than when the process of finish-grinding is used.

WE normally grind the teeth of gears after the heat-treatment. This paper will have particular reference to automobile transmission gears, which constitute a very large part of our work. Very few gears are made by grinding teeth that have not been heat-treated. We had experience last year with two lots of soft oil-pump gears that were sent to us by different manufacturers as being noisy. In both cases we returned the gears with the advice that they were cut very accurately. When they were received by us they could hardly be forced together on their true centers; they were soft and required only additional backlash to provide oil clearance.

Many instruments that have been designed to show tooth curvature are of great assistance in securing accurately cut soft gears, as they enable the operator to keep a careful check on the production of the machine that is more valuable than the current practice of rolling gears together on studs. Accurately cut gears will be greatly distorted by the later process of heat-treatment which distorts the teeth so that, unless they are ground, quiet, accurate movement is impossible.

The importance of grinding the bore and face of automobile gears has been well known for years, and great progress has been made in this work. It has been customary from time to time to finish-grind one part of the automobile and then another after heat-treating it. The grinding takes the place of the old method of finish-machining the parts before heat-treating them and then fitting the badly shaped parts together by touch or measurement. Gear teeth, so far, have not been given the same attention and poorly finished gear teeth and distorted tooth-shapes have been assumed by some manufacturers to be unavoidable. We bespeak for gear grinding your favorable consideration as being a logical development and an accurate process.

H. J. Eberhardt recently pointed out[2] the progress that has been made in the finishing of gear teeth. He showed that during the first period of their efforts the manufacturers used forms and cutters made in the tooth-form, and that many such machines listed in old catalogs had been abandoned; that in the second period generating machines were used to cut the teeth; and that in the third period the cutters and the gear teeth were ground after being hardened.

Salvaging Versus Finish-Grinding

There are two large volumes of gear-tooth-grinding business: first, the salvaging of gears that have been rejected as noisy or ill-shaped; and, secondly, the finish-grinding of gear teeth on which there is sufficient grinding stock left to allow accurate grinding.

The bulk of gear-tooth grinding, in the years gone by, was in the salvaging of gear parts that had been rejected in automobile transmissions. When manufacturers had gear trouble it was possible to take noisy gears that had already been cut to size, and to resurface them to an accurate tooth-form that would run quietly in a transmission. A large number of the gears furnished for salvaging were badly distorted by heat-treatment; a smaller number were originally cut to an inaccurate tooth-form. It is possible to grind the surface of such gear teeth so that the tooth-form shall be true and give quiet operation.

The grinding of salvage gears removes a certain small amount of stock from both sides of the tooth. This stock is from 0.003 to 0.006 in. in depth of cut and represents an average reduction in the chordal thickness of the tooth at the pitch circle of 0.008 in. This does not mean that 0.008 in. is removed from the entire surface of the tooth. This 0.008 in. represents the normal maximum increase in backlash in a given gear; such gears mated together are increased in backlash to a maximum of 0.016 in. Many gears salvaged in this manner require the removal of only 0.002 or 0.003 in., the backlash being 0.004 in. in a given gear, and 0.008 in. in a pair of such gears mated together. The backlash introduced into the gears when salvaged varies with the degree of inaccuracy in the product and not by the amount of stock necessary to be removed in the grinding operation.

A majority of mechanics and superintendents believe that the introduction of additional backlash will cause noise in the gears. We find that most of the noise usually attributed to additional backlash can be credited to the improper introduction of excessive backlash, as it is customary for manufacturers to secure backlash by pushing the cutters out of the true position, thus misplacing the tooth-form.

We have tested a large number of transmissions with ground gears that had backlash as high as 0.030 in. yet were quiet in operation, the only noise in the gears occurring when the car surged and the car speed exceeded the engine speed, the backlash accumulating into a single tap as the car surged. With proper backlash the oil-cushion between the teeth reduces the noise due to the surging action. Other than this single tap with each surge of the car there is no noise, no growl, no hum, no sing. When the car surges into second speed the backlash between the four gears accumulates and will cause

[1] Vice-President, Gear Grinding Machine Co., Detroit.

[2] See *Mechanical Engineering*, August, 1921, p. 530.

the single tap already mentioned, but otherwise four such gears with a total backlash of 0.060 in. will run quietly under normal operation.

During the last year we have salvaged for one firm 40,000 gears that were finish-cut before heat-treatment, and 35,000 for another company. Such salvaging is usual in the building of automobile transmissions, and this class of work will continue to be a factor in the gear-grinding business just so long as the attempt is made to finish the teeth before heat-treating them.

The finish-grinding of gear teeth having grinding stock constitutes the largest volume of gear-tooth grinding. The gears are furnished with the teeth made to normal machine limits, not to gear limits. These limits are easily maintained by any method of gear-tooth cutting and the practice is the same as is customary on so many other standard parts of an automobile. It is usual for us to receive such gears rough-cut or hobbed, by a single cut, with a variation in the tooth thickness of from 0.006 to 0.010 in. over the required size of the finished tooth. The grinding stock, approximately 0.003 in., that is removed from each side of the tooth during the grinding operation, is usually sufficient to eliminate the distortion due to heat-treatment. The limits of 0.006 to 0.010 in. over the required tooth thickness allow cut-gear blanks to be produced rapidly by the most ordinary processes of gear-cutting.

The main pinion, or sleeve-gear, in many cars is designed so that the teeth on the gear mesh with the internal teeth of the second-speed sliding-gear, and it is desirable that these two parts fit together accurately. When grinding these pinions it is usual for us to fit them to their mating second-speed gear. On the main pinion we prefer to have grinding stock of approximately 0.008 to 0.012 in. over the finished thickness of the tooth in order that an accurate, tight fit between these parts can be made.

The change in gear-tooth grinding from the salvaging of mis-shaped teeth to the finish-grinding of new product with grinding stock is the natural result of increased knowledge of gear-tooth grinding. Most manufacturers who now use grinding as the finishing operation began by using it as a salvaging operation. They found that the process was successful, and having been led to investigate the finish-grinding of rough teeth, they found that the expense of the finish-grinding process was relatively small when compared with that of gears cut to size and distorted by heat-treatment.

Cost of Grinding

The cost of the finish-grinding of roughed gears has been proved to be less than that of the usual process of finish-cutting, heat-treating and salvaging. In making a comparison of costs, it is important that the overhead expense of finish-cutting should bear the burden of the rolling, mating, scrap loss, sizing, running in of gears, changing transmissions on account of noise, and all other expense items that are so prevalent in finished-gear work. This total expense should be applied against the finishing operation, when the cost of finishing is compared with that of ground gears as grinding the gears eliminates all these items. We take gears that have been rough-machined and heat-treated and finish-grind them to a true tooth-form with a scrap loss that normally is less than 1 per cent. We thus assume the burden of all the above features of gear production.

Many manufacturers have found that the total cost of a finished transmission, accepted and placed in a car, is less when the gears are finish-ground after the heat-treatment than when they are finish-cut before the heat-treatment. Automotive manufacturers who have handled similar operations have changed from the old method of selecting the product and fitting the mismated parts to the better method of finish-grinding the parts to accurate limits. It is now standard practice to finish-grind all the essential parts of the car after heat-treating them, as it has been found that this practice is more economical in the end than machining the parts before heat-treating them.

History of Gear Grinding

Attempts at gear grinding have been numerous. Records show that as early as 1874 a man molded a wheel to the approximate shape of a gear tooth and used it for cleaning the surfaces of cast gear-teeth. He found the cast gears rather rough when they came from the foundry, so he put a molded wheel between the teeth of the cast gear and removed the burrs and the projections. H. M. Leland of Detroit developed the Leland-Ferris bevel-gear grinding machine, in which the edge of a wheel was used against the gear tooth and the tooth curve was generated to an approximately true curve. This occurred about 1898. There have been many other attempts at gear grinding. To grind gears accurately is an art; it has been attempted by many, but has been accomplished by few.

Our types of machine, made according to the Ward design, are described in a subsequent paragraph. They are illustrated in Figs. 1 and 2. We have developed a large amount of special equipment for the handling of gear-tooth grinding that has not as yet been placed on the market. It has been our purpose to continue the development of this equipment until we can handle the gear-tooth grinding of all types of gear.

Gear-tooth-grinding jobs of many sorts come to us. The large gears used on electric locomotive drives are sent because the finish cut gears develop so much noise after the heat-treatment that it has been found necessary to grind them in order that they may operate accurately without noise and have longer life. The machining of manganese-steel gears containing 13 per cent of manganese is a difficult job and is feasible only with a grinding wheel. We have ground the teeth of such gears up to 20-in. face, ¾-in. pitch and 3 to 4-ft. diameter. Some of these are shown in Fig. 3. In some instances the tooth shapes were ground out of the solid blanks. Grinding from the blanks was thought desirable because the distortion of the cast gear-tooth of high-manganese steel is very large. Some of the manganese gears were too wide for our early types of machine, but we were able to mount the gears on an arbor, grind the faces of the teeth in one direction, then reverse the gear on the arbor, grind back again to the other grinding cut and, by careful and accurate alignment, make the grinding cuts meet. Airplane gears require accuracy and long life. A large number of tractor gears are salvaged after the heat-treatment. The distortion in such gears frequently causes more noise than a tractor engine with the muffler open. Many thousands of these gears were too noisy for open-air use on tractors. Plain bevel gears such as are used normally in rear axles have been ground by us in large quantities. These types give a fair idea of the variety of gear work that we handle commercially and indicate the wide range of the requirements for grinding gear teeth.

Types of Machine

Our machines are built in either the planer or the shaper type, the emery wheel taking the place of the

cutting tool. The shaper-type machine is shown in Fig. 2. The wheel is mounted so that its formed face passes through the gear-tooth space, grinding both sides of the tooth and the bottom at each cut. Gears are mounted on this machine either singly or in groups as conditions allow. Where a number of gears are mounted on an arbor they are brought into accurate alignment, then the wheel passes through the tooth spaces of the several

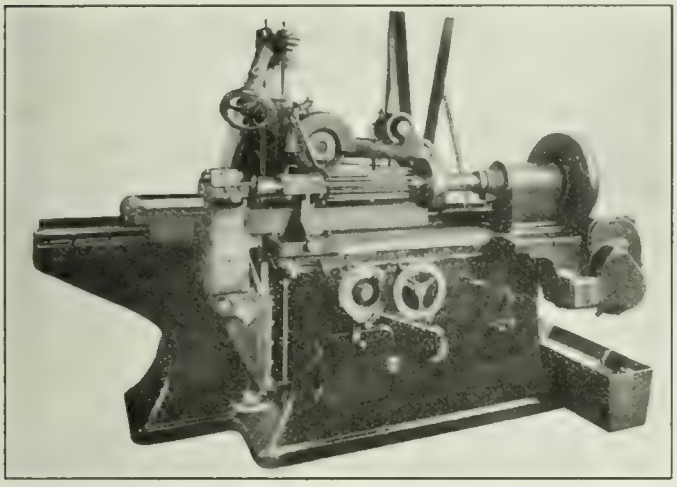


Fig. 1—The Planer Type of Gear-Grinding Machine

gears. After this the arbor is indexed, the wheel again passes through the next tooth-space and the operation is repeated around the gear.

The shape of the wheel used in grinding is accurately formed by diamonds that scribe or cut the tooth-form on the face of the grinding wheel. Those who have tried to shape wheels for other purposes may find it hard to realize that we are able to perform this operation accurately and quickly. The operation of shaping the wheel has been well standardized and brought down to a production basis and occupies only a fraction of a minute. We grind 150 sets of gears per day for one company and 100 sets for another firm in continuous production. The operation of the machine is so accurate and simple that, having completed an arbor of say eight gears, the variation in the grinding on the different gears will not be sufficient to register on the testing apparatus.

Tooth-Form

Aside from the errors of distortion from heat-treatment, there is probably no error that has so great an influence on production as the variation of the tooth-form. We have known men to hide away certain cutters that they felt were producing gears accurately, to save them for emergency use. Recently a cut gear was sent to our company by such a man, who stated that he had been cutting gears successfully with the same cutter for 4 years and had saved it especially to cut more gears when needed. He said that his recent trials had not been successful, that the gears produced were very noisy. After making a laboratory examination of the gear, we found four different shapes of teeth on the gear that were far out of true. The gear-tooth forms were high and low. This defect was due largely to the heat-treatment, but the tooth-form on the gears indicated that the cutting was inaccurate, and that the cutter had been improperly set in position.

It is true that many gears are cut wrong when soft, but the percentage of finish-cut gears that pass through

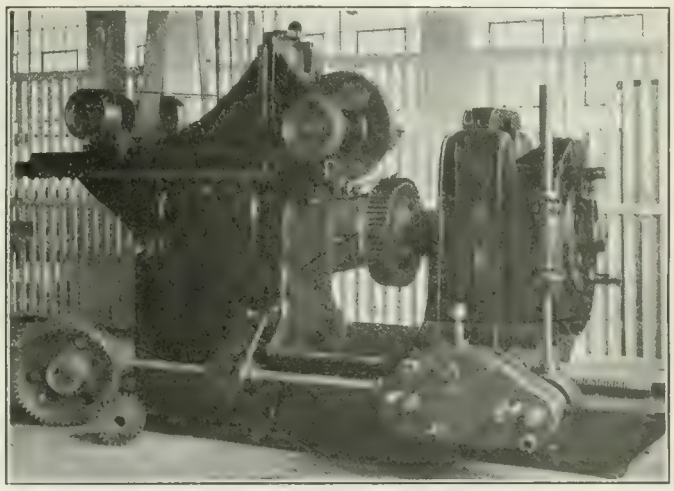


Fig. 2—A Gear-Grinding Machine That Operates on the Same Principle as a Shaping Machine

heat-treatment without any distortion is really very small. With the instruments available to-day, it is possible to determine variations in gear teeth after the heat-treatment. We recommend that tooth-form indicators be used. It is a good practice to put the finishing operation on the gear teeth after the heat-treatment; even if there is no other reason, surely the lessened interruption to pro-

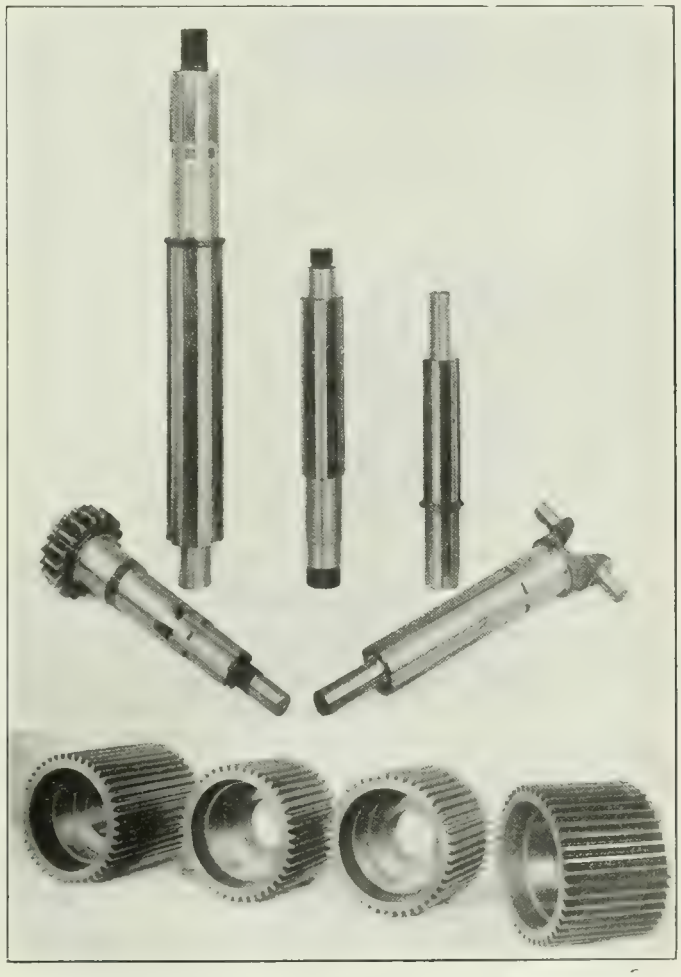


Fig. 3—Two Typical Examples of Ground Gears
The Upper View Shows Splined Shafts and a Stem Gear; in the Lower Power Motorboat Gears Having 44 Teeth and a Diametral Pitch of 3 Are Illustrated

duction will have weight. A manufacturer recently determined that it cost $19 to take out the transmission from a finished car and replace the noisy gears. He was then tearing down 50 cars per day.

Gear Wear

Much has been said recently concerning the wear of gear teeth. Special steel and methods of heat-treatment have been recommended in an effort to limit the amount of wear. All such efforts are worthy of consideration. Improper tooth-form causes abrupt acceleration and retardation that occur at least once for every tooth-contact, and is a large factor in tooth wear. Improperly shaped teeth accelerate the normal wear.

An article on the Investigation of Tooth Wear with Automobile Gear Steels, by E. R. Ross,[3] was submitted to the American Gear Manufacturers' Association at its October, 1921 meeting, in which much was said concerning the wear of gear teeth. This article shows where the wear starts and how it continues along the tooth as the gears run together. After the wear starts, it will cut into the surfaces and continue to grow along the teeth. The rate of wear is dependent largely on the material of which the gears are made, the method of heat-treating them and the distortion in the tooth-form that causes the wear.

With regard to other parts of the car, it has been proved, as it has been for gear teeth, that properly shaped surfaces, when finish-ground and running in oil, will last for a long time without an objectionable amount of wear; it has also been proved that any improper shape of the parts and rough surfaces will cause an acceleration in wear that makes for bad operation of the parts.

The grinding of gears is commercially a production operation. Its aim is the placing of the correct tooth-shape and the proper surface-finish on the gear-tooth so that the gears can move accurately, noiselessly and without wear. The cost of finished acceptable transmissions is less when finish-grinding is used. [The discussion of this paper is printed on p. 185.]

[3] See *Automotive Industries*, Nov. 3, 1921, p. 865.

THE BUSINESS OUTLOOK

A CAREFUL study of business statistics will convince one that there is not the regular periodicity about business cycles that is commonly assumed. There are many factors that may retard or hasten the movement; and in addition there are many modifying factors in such a relatively new industrial country as the United States. Daring and risk-taking have played such a large part in business success in this country, and business activity of a relatively high degree has been so much the normal condition, that it is difficult for many to believe that anything is normal except large profits and intense industrial activity. As industry and business become better organized, as control is more centralized and as more information about the market is available, such as probable demand, probable costs and probable supply, planning in advance becomes more possible.

Goods and services are ultimately always worth what the consumer will pay for them and not simply what the producer thinks they are worth or even what they have cost him to produce. Prices cannot for any long period of time remain below the cost of production. But for some time, costs of production may not be secured due to the fact that production costs fall out of their normal relation to the permanent basic value of the product. We passed through a period of feverish industrial activity, enormous speculation and very high prices, followed by a period of drastic liquidation.

There may be little new in the purely ethical world, but in Man's reaction on Nature; that is, in the technological world, in industry and the sciences, there is much that is new. Our whole industrial and financial organization and structure is different from that of the post-Napoleonic or of the post-Civil War periods. Business is better organized and systematized. More is known about the market. News is rapidly disseminated over the world. Capital flows readily from one nation to another.

Readjustments of various kinds must still take place before the effects of war-time conditions can be wholly eliminated from consideration. This is especially true of the maladjustment that still exists between various commodities and certain classes in the community. The tendency of prices, at present, is upward, but not uniformly so, with the result that, on the whole, a better equilibrium of the price level is gradually being obtained. While business will doubtless continue on the upward trend through the larger portion of 1923, there are too many obvious adjustments which must be made that will prevent the upward movement from being carried along to any undue heights. Since transportation facilities cannot be quickly expanded, they constitute a severe handicap to the fullest expansion of business. Conditions abroad are approaching the point where force of necessity will compel some fundamental readjustments.

Our strong financial position is one of the few favorable factors in the international financial situation. Strong as this position is, it should not be assumed that the apparent strength is of such proportions as to warrant anything but a conservative credit policy. Great burdens in the way of assisting in the flotation of long-term investment securities have been placed upon the commercial banking structure of this country in recent years. It is doubtful whether the securities now in the hands of banks could be liquidated in large volume as easily as some would lead us to believe.

Among the outstanding factors in the present situation are:

(1) The present tendency of business is upward, but further increases above the existing physical volume of trade are handicapped by the lack of adequate transportation facilities

(2) The upward movement of prices may well continue in the case of some classes of commodities, but there will probably be a marked resistance to too rapid and too great advances in the case of consumers' goods. One of the unfortunate effects of the transportation situation is that it may produce a temporary "place scarcity" of some commodities, with the result that some unhealthy price advances may occur

(3) Wages, like prices, will probably reach higher levels in some lines of business. This, coupled with higher raw-material costs, in the face of a resisting market, will probably tend to restrict industrial profits, even though business activity continues at a relatively high level

(4) While the Federal Government has been making some progress in reducing expenses, there is no sound basis for assuming that any material reduction in taxes can be expected in the near future. As a matter of fact, if some of the plans that are now under consideration are put into force, taxes may tend higher rather than lower.—W. F. Gephart, Vice-President, First National Bank of St. Louis

Passenger-Car Developments and Prophecies[1]

By F. E. Watts[2]

THE past year's progress has been in two apparently divergent directions; one toward better performance and the other toward cheaper production. In the first class of changes, the engine has received most attention. The fundamentals of crankshaft design are being evolved and the variety of multiple-bearing shafts, disc-cheek shafts, counterweighted shafts, and the like, together with the use of double flywheels and of dampeners, shows that finality has not been approached. Naturally, this work has drawn renewed attention to the desirability of light reciprocating parts. In many cases this has resulted in the adoption of aluminum-alloy pistons and, in some few cars, forged-duralumin connecting-rods are being used. This last is a most significant development. Price alone stands in the way of a considerable use of the new aluminum alloys. It is to be hoped that aluminum manufacturers will find means during the coming year to reduce their costs, so that they can get the quantity business so vital to their industry and to ours.

Only meager progress has been made toward the better utilization of fuel. A majority of European cars have adopted higher compression, and use heavy thick-headed aluminum pistons, for thermal reasons only; but in this Country, where smoothness is more important than fuel economy, the light-weight split-skirt piston with narrow rings, often four or more per piston, predóminates.

Developments in combustion-chamber shapes and in manifolds have not resulted in much change commercially.

The use of doped fuels is not commercialized as yet. All these are subjects of that fundamental research which is itself one of the most important and gratifying features of the year's progress.

Air-cooling will come to the front as an issue in 1923. So will the so-called "steam-cooling" systems, if the patent situation clears.

Ignition, starting and lighting developments show only detail improvements in this Country; but the combined generator and magneto has had important development abroad. The coming year may see progress in American machines of this type.

Camshaft design has made considerable progress, chiefly in the direction of securing quiet valves with considerable clearance between the valve and the tappet. There is a marked tendency toward the adoption of chromium and silicon alloys for poppet valves. Both these improvements increase the mileage between overhaulings.

Much development work is being done on sleeve-valve engines, and also on fuel-injection systems.

Three aids to engine durability have begun to attract attention. They are aluminum-alloy piston-heads that reduce the carbonization of the crankcase oil; oil stills that remove unvaporized fuel from it; and air-cleaners that prevent road dust from being carried into the engine with the carbureted air. At present, it is impossible to foretell the value of any of these.

The plate clutch has been developed to a point where it is evident that it will replace all other types for moderate powers.

In change gears the outstanding features are an increased adoption of high-carbon alloy gear-steels in this Country, in contrast to the continued use of case-hardened steels abroad; the continued increase in the use of ground gear-teeth; improvements in gear cutters and gear teeth due to optical methods of testing; and the tendency in Europe to reduce the number of forward speeds from four to three, in spite of the high price of fuel.

Universal-joint makers are preparing to give us shafts that will run reasonably true and not wear too rapidly. This is being accomplished by the use of oil lubrication on the metal joints, centering devices on the fabric joints and tubing of better quality in both types.

Rear axles have not been greatly developed. Front axles remain about the same as a year ago except that, in Europe, the increasing adoption of four-wheel brakes has brought new problems. A number of American cars will be equipped with brakes on all wheels before the end of 1923. They increase the safe speed of operation, but add complications such as cost and unsprung weight.

Steel wheels, both disc and spoked, are being developed very rapidly. Large-section thin-walled tires, such as 32 x 6-in. and 34 x 7-in., are being made experimentally. They give promise of superior riding qualities.

Chassis-suspension improvements are matters of detail, except that fabric and rubber shackles and supports have made real progress.

Fabric engine supports have made their appearance, and probably more of these will be seen this year.

Chassis frames in general are heavier and stiffer; this is due partly to the increasing number of closed bodies.

Closed-Body Quantity-Production

The most outstanding development of the year, however, is the adaptation of the closed body to cheap quantity production. Starting with four and five-passenger two-door bodies, rapid production methods have spread to other types. Cheaper framing, the development of unit assembly and progressive final assembly, and the adoption of belt molding in place of the overlapping joint are a few of the items that have contributed to lower costs. Two new styles have been evolved, the business coupe and the business sedan. They open closed-car markets that have scarcely been scratched.

Further development of closed bodies is proceeding along the two lines of the all-wood-and-fabric job, and the all-metal enamelled-job with detachable upholstery.

With a demand for closed cars estimated at between 40 and 60 per cent, it becomes increasingly important to get them out quickly and cheaply. To this end quick paint and enamel processes are being developed. The

[1] Annual report of the Second Vice-President representing passenger-car engineering.

[2] M.S.A.E.—Chief engineer, Hupp Motor Car Corporation, Detroit.

progress being made in regard to body hardware is astonishing.

Bodies, tops and seats are lower, and radiators and hoods are higher than formerly on most recent designs.

The "cubic capacity" of the bodies is less, which aids in the cheapening process that is going on in all the important details of the car. This process will, next to closed-body changes, be the most important development of 1923. It is the result of price competition.

Only one important step has been made toward the light car of the future. I refer to the new four-cylinder Lancia; with a 122-in. wheelbase, a 50-hp. engine and a touring body, it weighs only 1650 lb. Apparently, its value as a guide-post to the industry is not yet realized.

JANUARY COUNCIL MEETINGS

THE 1922 Council held the last sessions of its administration on Jan. 8 and 9, at New York City, the following being present: President Bachman, First Vice-President Whitbeck, Vice-Presidents Young and Watts, Past-President Beecroft, W. R. Strickland, H. M. Crane, W. A. Brush, C. F. Scott, H. W. Alden, A. W. Scarratt, F. W. Gurney and E. A. Johnston.

The financial statement showed as of Dec. 31, 1922, a net balance of assets over liabilities of $125,909.84, this being $8,341.90 less than the corresponding figure on the same day of 1921. The income of the Society for the first 3 months of the current fiscal year amounted to $68,106.40, including receipts from the sales of annual-dinner tickets. The operating expense during the same period was $64,673.88.

Forty applications for individual membership and 17 for student enrollment were approved. The following transfers in grade of membership were made: From Associate to Foreign Member, H. H. Winburg; Junior to Member, Julius F. Melzer and John M. Wood; Associate to Member, C. B. Curtiss and Edward Wotton; Service Member to Member, Frederick Y. Dawson, H. S. McDewell, Frederick A. Truesdell, H. C. Wilson and G. E. A. Hallett.

The following subjects were assigned to the Standards Committee:

High-Chromium Steel—Iron and Steel Division
Molybdenum Steel—Iron and Steel Division

At the session of the Council held on Jan. 9 Chairman Johnston, of the Standards Committee, reported in detail the action taken by that committee on the same day with regard to the proposals of 17 of its Divisions as set forth elsewhere in this issue of THE JOURNAL. The proceedings of the Standards Committee were approved for submission to the Society in meeting assembled on Jan. 10, for consideration in the matter of referring the recommendations of the Divisions by letter-ballot to the voting members of the Society for final adoption.

ORGANIZATION SESSION OF 1923 COUNCIL

The organization session of the 1923 Council was attended by President Alden, First Vice-President Crane, Vice-Presidents Masury, Warner and Scarratt, Past-President Bachman and Councillors Swetland, Scaife, Scott and Chryst.

President Alden announced the personnel of the 1923 Administrative Committees as follows:

CONSTITUTION COMMITTEE

C. B. Veal, *Chairman*

W. A. Brush — A. L. Riker

FINANCE COMMITTEE

H. M. Swetland, *Chairman*

Fred Glover — C. B. Whittelsey
E. S. Jordan — K. W. Zimmerschied

HOUSE COMMITTEE

C. F. Kettering, *Chairman*

A. J. Brosseau — Milton Tibbetts
E. A. Sperry — John Younger

MEETINGS COMMITTEE

M. P. Rumney, *Chairman*

O. C. Berry — T. Milton
T. J. Litle, Jr. — C. F. Scott
Thomas Midgley, Jr. — E. P. Warner

MEMBERSHIP COMMITTEE

L. R. Smith, *Chairman*

W. C. Keys — C. W. Stratford
H. J. Porter — A. M. Wolf

PUBLICATION COMMITTEE

E. P. Warner, *Chairman*

H. C. Dickinson — F. C. Mock
D. L. Gallup — O. E. Hunt

SECTIONS COMMITTEE

H. W. Slauson, *Chairman*

W. A. Brush — B. F. Kelly
H. R. Corse — O. A. Parker

President Alden announced that Past-President B. B. Bachman had accepted the chairmanship of the Highways Committee.

The following transfer in grade of membership was made: From Associate to Member, Mason P. Rumney.

Discussion was had as to the program of meetings outlined by the Meetings Committee for 1923.

The names of the members who will serve this year as Chairmen and Vice-Chairmen of the Standards Committee and its Divisions were reported. These are listed in this issue of THE JOURNAL, as well as those named by the Council for service on the various Divisions.

The next meeting of the Council was scheduled to be held in New York City on Feb. 26.

Hobbing-Machine Operation

By John Edgar[1] Detroit Section Paper

THE author discusses briefly the major factors upon which the successful operation of hobbing machines depends. A distinction is made between difficulties that are presented by the hob itself and those due to the machine, suggestions for surmounting these difficulties being included. Emphasis is placed upon the fact that a hob is a precision tool, accurate within tenths of thousandths of an inch.

Methods of securing rigid rotation, the avoidance of run-outs, concentricity of rotation, accuracy of indexing, proper maintenance and other features are indicated. The condition of the finished tooth-surface is divided into two classes and commented upon, the influence of the holding devices used being mentioned. The author concludes that much of the dissatisfaction encountered in the hobbing process can be overcome if more careful set-ups of the hob and the work are made.

MANY engineers do not appreciate the full extent of usefulness of the hobbing process. A better understanding of its capabilities will do much to overcome their antipathy. Any suggestions that aid in better adapting its peculiarities to the needs of those who favor its use are always appreciated. The human element enters into its employment as in any other process of manufacture, and, to get the greatest benefit from its wonderfully simple operation, conditions of usage must be given proper attention.

As the quality of results is a varying factor in the discussion of any process, there being no well-established limits of toleration in general use in the somewhat mysterious generating processes, no great reliance can be placed upon the phrases "high quality," "accurate," "extreme accuracy" and "good finish," as comparing units. To obtain a comparative unit that can be used in a general discussion, one must be limited to some definite terms as is now generally the case in the processes of manufacture where the fine measuring instruments obtainable can be used and a fractional limit can be stated. The gear-cutting industry does not seem to have arrived at that state. Until some of the instruments now under development are perfected, there is bound to be much confusion and misunderstanding.

The Hobbing Process

The hobbing process, as well as other processes used in the production of gears for transmission and for timing-gear trains, will therefore continue to suffer as in the past. As a result, the process is made to shoulder much of the blame that should be placed elsewhere. There seems to be no better remedy for the difficulty in the meantime than the expensive process of meeting each case on its own merits. We hope that the final result of present development will make it possible to measure a gear in a conjugate sense with as definite results as we now measure a shaft for diameter and length.

In itself, the hobbing process presents few if any mechanical difficulties. Its mechanism is simple and direct in action; the one-way direction of movement eliminates many elements that we find to be trouble producers in other processes. Once properly adjusted, the mechanism will operate without further attention for a given length of time with good results; whereas, in alternate mechanisms, frequent and expensive adjustments and replacements are required if an equal degree of accuracy is desired.

The reason for any mechanism on machine tools is to work a tool in proper conjunction with the blank being operated upon. This is met in the hobbing machine when we get the hob working in proper relation to the gear blank. When we desire a quiet-running accurate gear, the hob must be a precision tool and, in making the ground hob to-day, the degree of accuracy required limits the toleration of error to tenths of thousandths of an inch in both lead and tooth outline.

Having obtained a hob of the precision type, we must follow in its use and in all the subsequent operations of sharpening and setting-up the same degree of care that is taken in its manufacture. Properly sharpened, this type of hob should not run out of true at the peripheral cutting edges more than a small fraction of 0.001 in., because any run-out there indicates a wabbly path of the generating edges. Provision is now made in the ground hubs at each end of the hob to check up the run-out of the hob as a whole when set up on the hobbing machine. These are supposed to show no movement of the indicator that is used for checking them.

Hobbing-Machine Operation

Assuming that the above conditions are met, we now come to other items that need attention to operate a hobbing machine successfully. The hob spindle should be run in closely fitting bearings so that no run-out is observable in its rotation, and all end-play must be eliminated. An indicator placed so as to check end-play should show no wabble of the needle when the spindle is rotating; in other words, the hob must be securely rotated in a fixed transverse plane and be concentric with the axis of rotation. The work spindle also must be held securely during its rotation in closely adjusted bearings, and the rotation of the work obviously should be concentric with the hole in the work spindle. The plane parallel with the sides of the gear should be perpendicular to the axis.

The accuracy of indexing is affected by the condition and the adjustment of the worm and the worm gear. The worm gear should be fastened securely on the spindle so that the pitch-circle will rotate concentrically with the axis of the spindle; also, it should have no side wabble. The worm should be adjusted until there is no appreciable end-play, and it should also run concentrically with its axis. The adjustment between the worm and the gear should be as close as it can be run without heating, which should be the case with little or no backlash in the mesh when run dry.

The intermeshing mechanism connecting the hob and the work spindles will not show any appreciable effect on the results if it is made to close commercial limits and kept in good condition. Bearings should not be

[1] Designing engineer, Barber-Colman Co., Rockford, Ill.

allowed to become too loose and gears too badly worn. Machines have been found in operation with the bearings worn so that the shaft would rattle in them and with gears worn lopsided, but they were still kept on production work with apparent satisfaction as to results. However, good results cannot be expected of any machine if it is not in first-class running-condition.

Operating Conditions

To just what extent the condition of the machine may show in the tooth bearing of the gears is a disputed question. It seems that we may divide the condition of the tooth surface into two classes; first, that which shows split and high or low bearings. Such bearings can safely be blamed upon the hob, because a regular wabbly condition of generating edges is the cause of the split bearing and also of the high or low and alternate bearing on the gear teeth. A wabbly lead or a run-out of form are the faults that should be remedied in the hob. These conditions could be obtained only in a machine, if the machine were at fault, in which the hob arbor is given a regular acceleration of angular velocity; but this is very unlikely to happen. If any variation in angular velocity does occur, the timing of the period would be altogether likely to be different for successive revolutions. This would lead to a choppy appearance of the tooth surface similar to that due to chatter, but not so regular and would tend to produce the appearance of a hand-scraped surface.

The second condition of tooth surface is that which shows a variation in the bearing along the face of the tooth parallel with the axis. This may show a bearing that alternates from one side of the tooth to the other with decided steps, or it may show what is termed a "cross-bearing," showing the bearing on alternate sides of the tooth at the extreme ends. This condition is due to the poor adjustment of both the hob and work spindles in loosely fitted bearings. Where this shows on the gears, the only remedy is to rescrape the bearings. Cross-bearings in spiral gears also are due to the use of change-gears that have not been properly computed.

When cutting helical gears, the amount of feed should be calculated to very close limits of from 6 to 10 decimal places, depending upon the width of the face. Spotty bearings in spiral gears may show a bad condition of the lead screw, due to either a drunken thread or to the thrust bearing being out-of-true. Where the lead screw is at fault, the fact can be determined by an examination of the gear, which will show a regular interruption of bearing across the face at intervals equal to the pitch of the lead screw measured parallel on the gear axis.

Holding devices often influence the finish of gear teeth and, in some cases where the layout is not carefully designed, they will produce bearings that cause the condition of the machine itself to be questioned. If the backing-up of the cut is not properly attended to, the strain set up by the cut will be gradually released when the hob is cutting through, causing a falling off of the bearing near the end of the teeth last operated on by the hob.

Cross-bearing is sometimes caused by a creeping of the work, due to its not being tightly held against the torsional thrust of the hob. This torsional thrust is not due so much to a wormlike thrust of the thread, but to the fact that the hob is set at an angle with the axis of the work so that a cross pressure is exerted. This condition is more often found where large work is being cut with merely the hubs of the gears as clamping surfaces. Creeping must be guarded against adequately in all spiral gear-cutting. Where possible, this can be effected by the use of a key.

When the work is clamped in gangs, the faces of the blanks must be parallel, within small limits; any error here will cause a run-out of the finished work. The actual error is difficult to measure after the work is clamped up unless the outside diameter is true with the hole, which is not often the case on production work. For accurate finishing-cuts, the policy of cutting but one gear at a time has much to commend it.

Everything that has been mentioned in this connection applies to the holding of silent-chain sprockets in the machine. To get the straight side of a sprocket tooth within the limits of error that the chain manufacturers require, necessitates the use of a hob of the high-precision type and extreme care must be used in setting it up. Hobbing splined shafts is a much more satisfactory proposition, because here we can work to definite measurable limits so that the confusion encountered in gear cutting is eliminated. Hobs for all finished work must be closely made as to form and carefully set up. Much of the dissatisfaction encountered in the hobbing process can be overcome if more careful set-ups of the hob and the work are made.

To those who use a hobbing machine daily, its operation becomes second nature. For that reason I have not mentioned various points that there may be some question about in the minds of many engineers. [The discussion of this paper is printed on p. 185.]

THE MOTOR TRUCK AND OUR RAILROADS

(*Concluded from p.* 154)

very brief. Barring a very small proportion, involving exceptional and unusual circumstances, all carload freight, even over very short distances, can be handled with far greater efficiency upon railroad lines than by truck. I think, therefore, the trucks should not seek to invade the carload field.

There is only one further thought that I wish to leave with you. The spirit in which all of our problems of coordination ought to be approached is one of live-and-let-live. For the men in both your occupation and mine, the primary purpose should be to guide the development of that relationship along sane and sensible lines, so that each form of transportation may be enabled to give to humanity the maximum service of which it is capable.

How to Use Gear-Cutting Hobs

By S. O. Bjornberg[1]

Detroit Section Paper *Illustrated with* Photographs and Charts

SINCE a gear is a product of the cutting tool, the gear-cutting machine and the operator, it can be no more accurate than the combined accuracy of these fundamental factors. All gear manufacturers aim to eliminate split bearings, high and low bearings, flats and other inaccuracies in tooth contour, because a gear having teeth the contours of which comply with the geometrical laws underlying its construction is by far the most satisfactory.

Illustrations are presented to convey an understanding of the geometrical principles involved, together with other illustrations of testing instruments and comments thereon. The application of these instruments is termed quality control, which is discussed in some detail under the headings of hob control, machine control and gear control. The author states that these testing instruments enable a gear manufacturer to know what results he obtains with gears, hobs and machines, and thus assist in the securing of a uniform product.

GEARS that run quietly constitute one of the important requirements in a modern automobile. Since noisy gears are always found to be inaccurate, the problem of how to manufacture accurate gears is the paramount issue of today in the many plants that make gears for the automotive industry.

All gear manufacturers aim to eliminate split bearings, high and low bearings, flats and all other inaccuracies in the tooth contour, the idea being that a gear

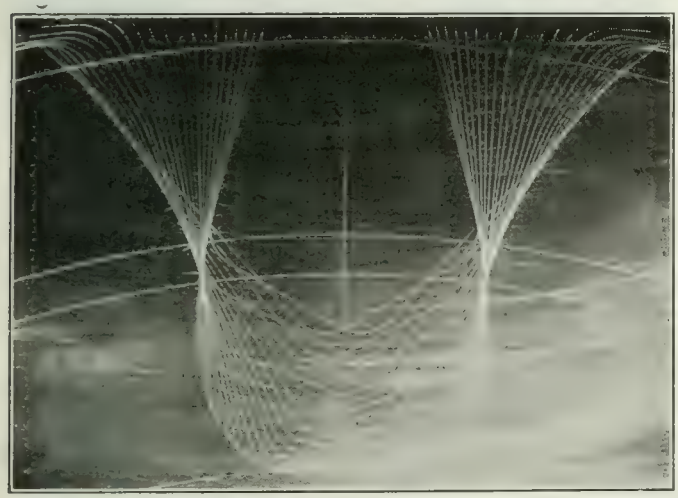


Fig. 1—Diagram Showing the Generation of a Gear Tooth by the Hobbing Process

having teeth the contours of which comply with the geometrical laws underlying its construction will make a better gear than one not having teeth so formed. A gear is a product of the cutting tool, the gear-cutting machine and the operator, and therefore it can be no more accurate than the combined accuracy of these three factors. If this fundamental statement is kept in mind by gear makers, it will go a long way toward eliminating gear trouble, provided the system of gearing used is correct theoretically.

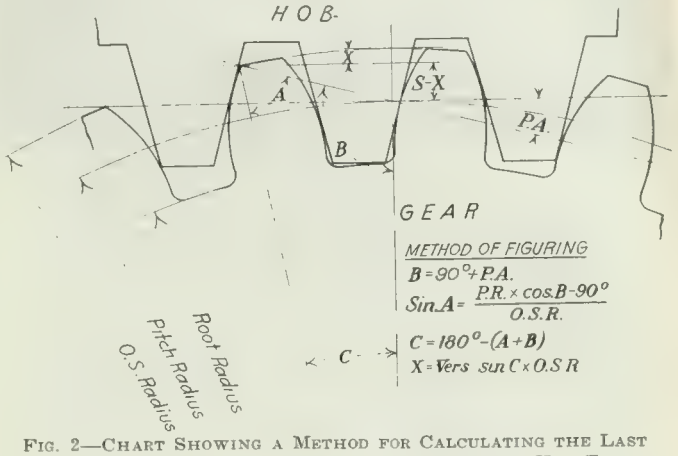


Fig. 2—Chart Showing a Method for Calculating the Last Point of Contact between a Gear Tooth and a Hob Tooth

We have developed a number of inspection instruments to control the manufacturing process of gears, based on the fundamental laws of gearing. These instruments will help the manufacturer to know what results he is actually obtaining in regard to his gears. We have chosen to term the application of these instruments quality control, and have divided it into the three phases of hob control, machine control and gear control.

In considering the hob, it is necessary to understand a

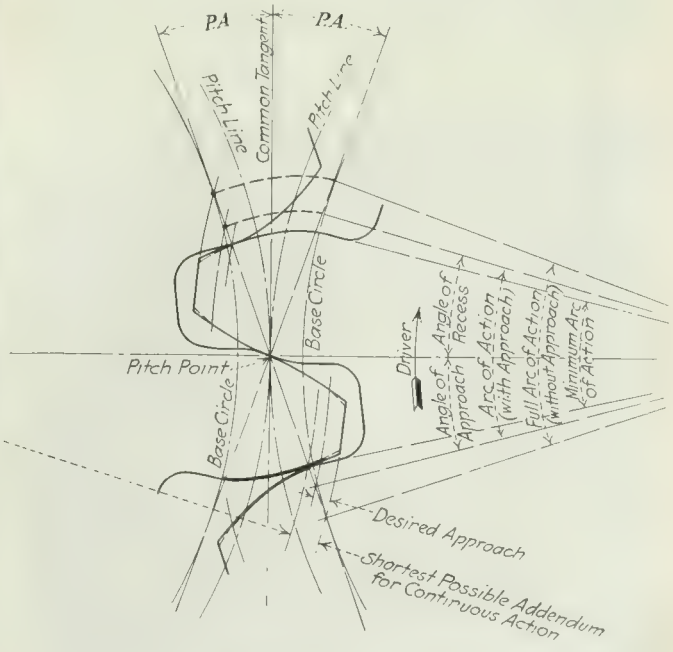


Fig. 3—Diagram for Determining the Arc of Contact between Any Two Mating Gears and the Length of Contact That the Involute Curve Has with Its Mating Gear Tooth

[1] Consulting engineer, Illinois Tool Works, Chicago.

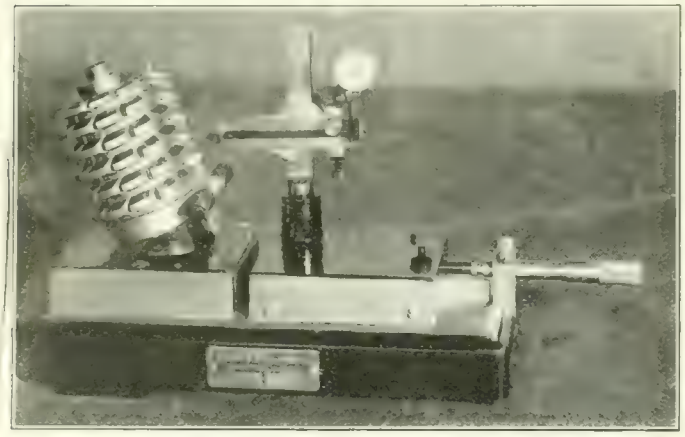


Fig. 4—A Hob in Place on the Contour-Testing Machine

few of the geometrical conditions involved. Fig. 1 shows a gear tooth being generated by the hobbing process, and how the successive cuts of the hob teeth form the involute curve. Fig. 2 is a chart showing a method of calculating the last point of contact that a gear tooth has with a hob tooth. Fig. 3 shows the calculations necessary to determine the arc of contact that any two mating gears have, and also the length of contact that the involute curve has with its mating gear tooth.

In designing a hob it is necessary to know what these contacts are, because the present type of involute gearing is usually made with small approach curves at the addenda, and the hob has to be designed so that it will produce the required approach curves without breaking the arc of contact of the mating gears. After making these calculations, a hob must then be produced that will fulfill these geometrical laws correctly, and it must therefore have the correct contour on all of its cutting teeth. It must also have all its cutting teeth in the true helical path and all its cutting edges concentric. To check hobs for the three fundamental requirements of correct contour of teeth, proper location of contour on the path of the helix and uniform distance of contour from the axis of the hole, we have brought out instruments that will indicate how closely the finished hob approaches the ideal conditions.

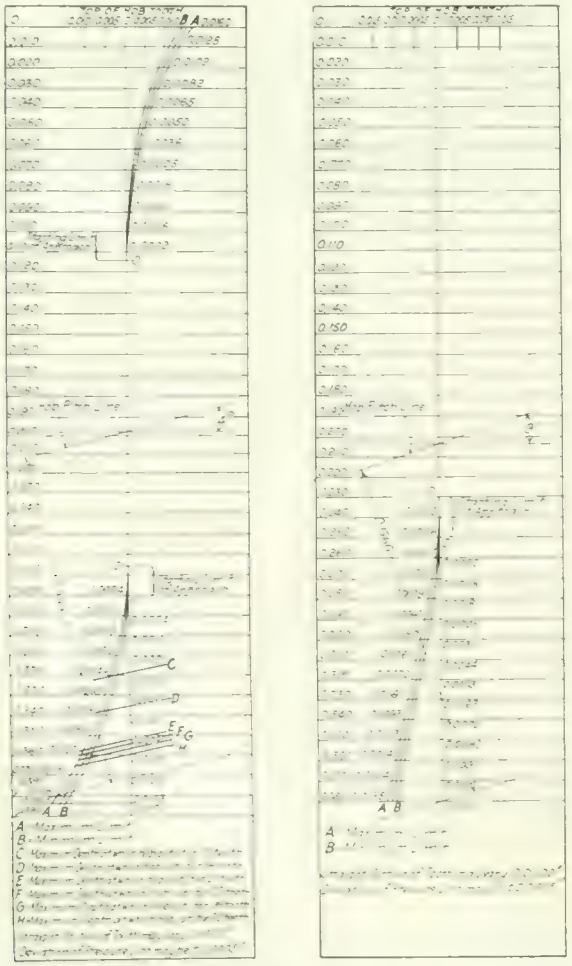


Fig. 5—Typical Examples of Form or Contour Charts

Hob Control

Fig. 4 shows a hob on the contour-testing instrument. The indicator arrangement is constructed so that a movement of 0.001 in. of the contact point is registered as 0.005 in. on the dial indicator. Therefore a movement of 0.0010 in. on the dial indicator gives a movement of 0.0002 in. on the contact point. By this arrangement, it is possible actually to check the contour of the hob tooth in ten-thousandths of an inch. The instrument is very sensitive and, as the contact is a knife-edge, it will actually register such elevations and depressions as would be caused by rough grinding. The indicator slide is fed inward in increments of 0.010 in. at a time, and the readings are plotted on a chart. By drawing a curve through these plotted readings, a graphic record of the hob contour is obtained.

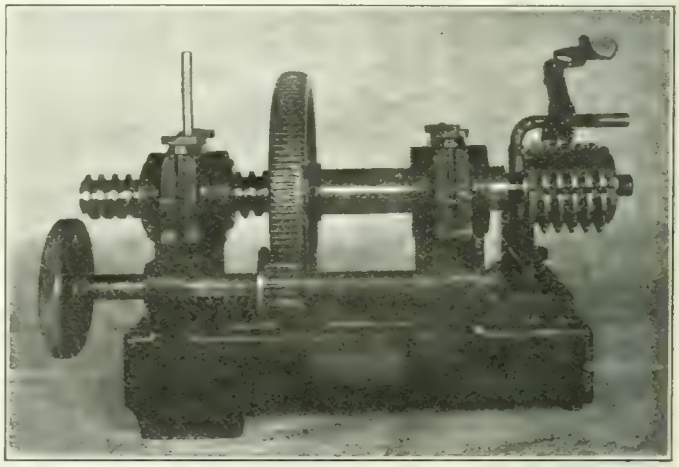


Fig. 6—A Hob on the Lead-Testing Machine

Fig. 5 shows several form or contour charts. On one of these charts the hob tooth has a curve at both the addenda and dedenda, the center line being the "master" form; the other two lines are tolerance lines, beyond which the form must not go. Should the hob be made to the extreme tolerance line at both addenda and dedenda, it will still cut gears that will roll without any interference, as these tolerance lines are placed so that they will not permit any interference. After it has been determined that a hob is correct in contour, it is then tested for lead.

Fig. 6 shows a hob on the lead-testing machine, which uses a master screw for each pitch of hob. The indicator arrangement on this machine also has a 5-to-1 ratio and will, therefore, register ten-thousandths of an inch. The contact point is brought against the cutting edge of the hob, and the indicator dial is set to zero. As the spindle is rotated, the hob is moved forward at the proper lead

and, if the hob has been made correctly, the indicator point should register zero on all cutting edges. If there is a weave in the helix due to grinding, or if the hole in the hob is large and, therefore, does not fit the arbor correctly, or if the gashes of the hob are not properly spaced, the indicator will register a great variation in the cutting edges as they pass by. Therefore, if the indicator point is considered as a gear tooth that is being cut, the necessity of having all of the cutting edges in a true helical path can be appreciated readily.

Fig. 7 shows two lead charts that have been plotted from actual hob readings. The points shown vary by ten-thousandths of an inch. The upper chart with the wavy lines shows a hob purchased in the open market. The lower chart shows a hob made to a specification, and this hob is extremely accurate. It is apparent that any deviation from the correct contour, spacing of the gashes and concentricity is detrimental. It is, therefore, necessary that the hob user at least provide himself with a means of knowing the concentricity in a hob, because a

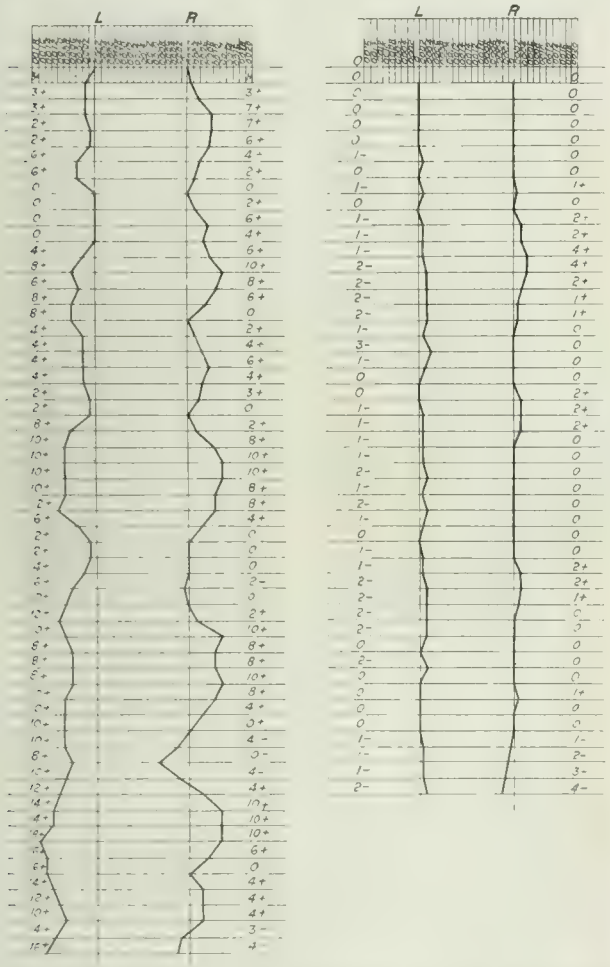


FIG. 7—TWO LEAD CHARTS PLOTTED FROM ACTUAL READINGS OBTAINED WITH THE MACHINE ILLUSTRATED IN FIG. 6

The Chart at the Left with the Wavy Lines Was Obtained from a Hob Purchased in the Open Market, While the Accuracy of a Hob Made to a Specification Is Evidenced by the Comparative Straightness of the Lines in the Chart at the Right

hob sharpener can spoil a good hob very easily by not sharpening it so that it is concentric.

Fig. 8 shows a hob on a fixture for testing concentricity and radial gashes. It is absolutely necessary that a hob be sharpened radially, because a hook or a drag on a hob tooth will raise and lower bearings on the gear teeth. It is necessary also that the gash be parallel with the axis

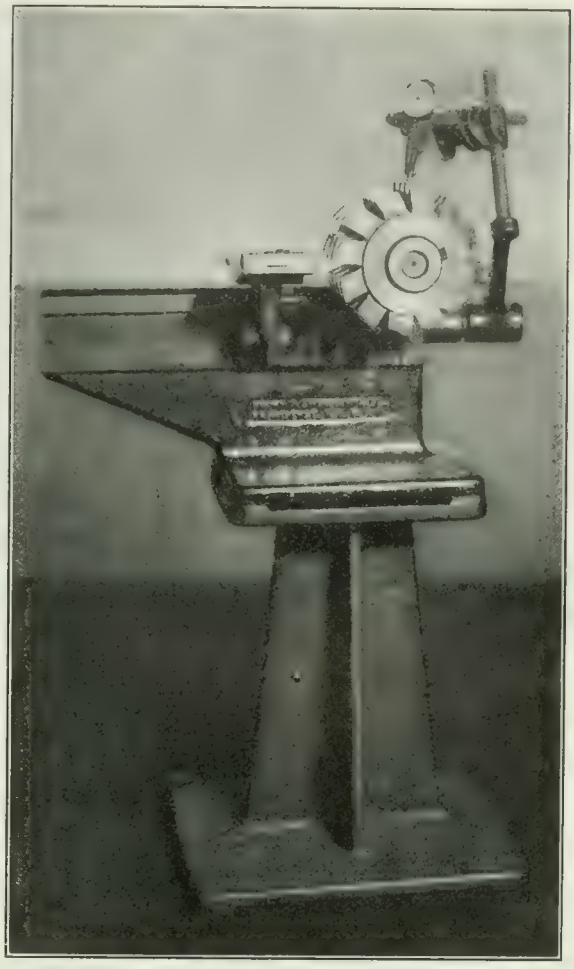


FIG. 8—A HOB IN PLACE ON A SPECIAL FIXTURE THAT TESTS CONCENTRICITY AND RADIAL GASHES

of the hob if a straight-gashed hob is used, or that it follow the true helical path if a spiral-gashed hob is used. The general practice is to use a hob in three or four positions and, if the gashes do not fall in their proper place, gear teeth of different contours will result from the different positions.

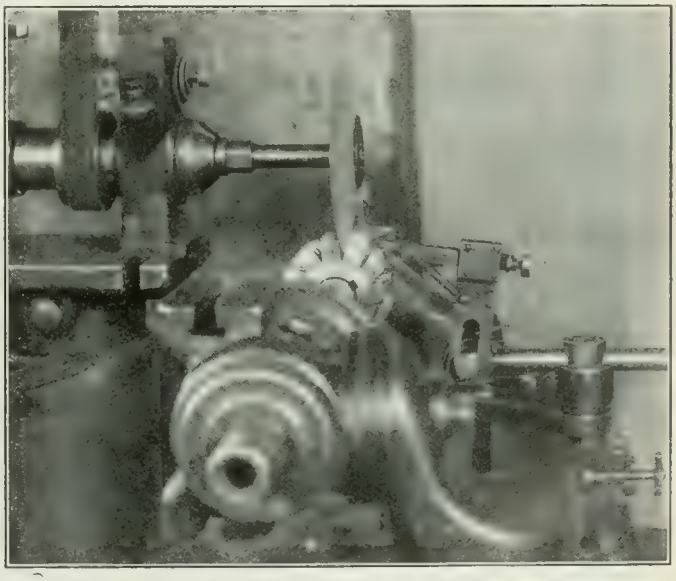


FIG. 9—A HOB BEING SHARPENED

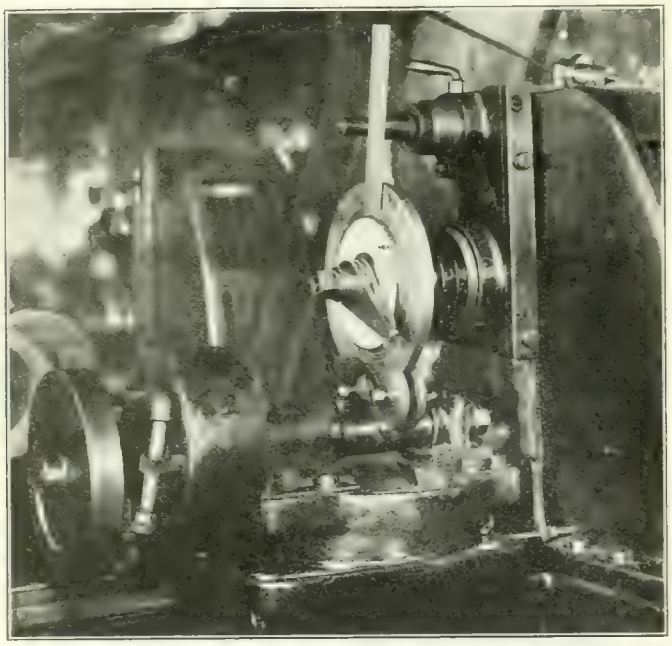


FIG. 10—TESTING FIXTURE THAT INDICATES THE UNIFORMITY OF THE MOTIONS OF THE HOB AND THE WORK ARBORS

Fig. 9 illustrates a hob on the sharpening machine and shows the position of the wheel and index finger. The cone side of the wheel is used in the sharpening of the straight-gashed hob. This method is strongly recommended because, if the cup side of the wheel is used on a straight-gashed hob, the wheel will grind more off the end teeth of the hob as it passes in and out, and will make a slightly warped surface on the hob teeth. By using these fixtures and methods, a hob user can check the hob he is buying and see that it comes within the limits of accuracy he has specified.

MACHINE CONTROL

A good hob does not always assure the production of good gears, because the second factor to be considered is the hobbing machine itself. One of the first requirements of a good hobbing-machine is that the velocities of the hob and the work arbors be uniform, so that tooth contours and spacings are regular. To test this uniform motion, we have designed the testing fixture which is shown mounted on a horizontal machine in Fig. 10. The idea of this fixture is to compare the velocity of the hob arbor with that of the work arbor. This is accomplished by having the work arbor carry an arm that rotates with it. A second arm is fastened to a disc, mounted loosely on the work arbor, the disc receiving its motion by frictional contact with intermediate rollers, the first roller being mounted on the hob arbor. Any variation of the velocity between the friction drive and the gear train of the machine will cause a displacement of the two arms, which is magnified by a system of levers and recorded by a stylus on a paper chart.

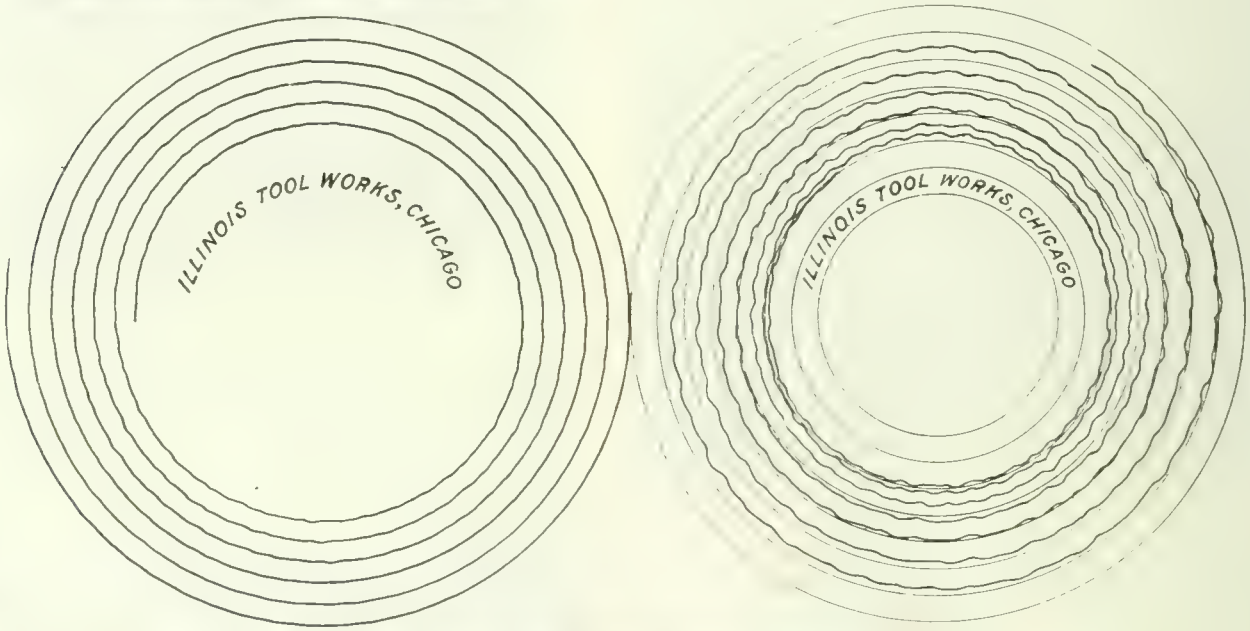


FIG. 11—CHARTS MADE BY THE TESTING FIXTURE ILLUSTRATED IN FIG. 10

Fig. 11 shows some charts made by this testing fixture. On the chart at the left the line is perfectly smooth; on the other chart there is a pronounced weave caused by some irregularity in the gear train of the hobbing machine. The machine that traced the wavy line cannot be expected to produce gears of great accuracy. With the instrument shown in Fig. 10, the gear manufacturer can easily discover why some of his gears show greater irregularity than others; also, he has the means available to check new machines he may desire to buy, and purchase only those that show true uniform motion.

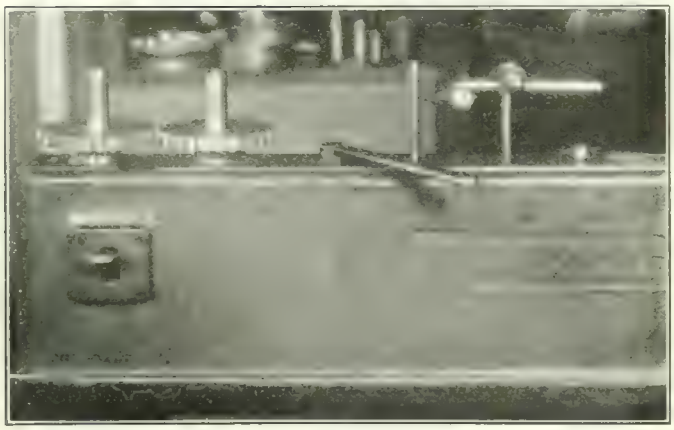


FIG. 12—VERNIER MACHINE FOR INDICATING THE CONCENTRICITY OF THE GEARS

In operating a hobbing machine it is necessary to give attention to the following points, which have an important bearing on the quality of the gears produced. The hob arbor must have all end-play eliminated and must run true. It happens often that the arbor runs true but, as soon as the hob is mounted, it is found to run out. This is caused by the threads on the arbor not being true with the axis of the arbor, or by the nut not being machined properly, which causes the arbor to spring when the nut is drawn up. These defects must be eliminated before good gears can be produced by the machine.

The springing of the work arbor, while not so serious, is also a factor to be considered. Gears made under this condition will run eccentrically on the test fixtures, which makes it difficult to check them properly. With the hobbing machine in good condition, a correct hob, properly machined work on hand, and the feed and index gears properly mounted, one would expect to obtain perfect gears; however, since the human element has not been eliminated in the operation of the machine, it is necessary to consider the personal equation.

Gear Control

To check the gears as they come from the hobbing machine, we use an ordinary vernier machine such as is shown in Fig. 12. This is the most common method of checking gears at present. It will indicate whether a gear is concentric and will show also how much jump there is between any two mating gear-teeth; however, it does not tell whether one of the gears is correct and the other incorrect, or whether they are both wrong, and how much.

Fig. 13 shows an involute testing-machine with a gear in place. This machine does not use bands, but the base circle of the gear rolls directly on the straight edge of the slide under spring pressure. The indicator will register the amount of deflection from the true involute path; therefore, it can be determined which of the two gears is incorrect and how much. If the involute curve is correct, the two gears should roll on the vernier machine without any jump per tooth.

Fig. 14 shows an angular-velocity testing-machine for gears. This machine consists of two pitch cylinders with a device for recording any variation in the angular velocity of the two gears. One of the gears is mounted solidly with the pitch-circle disc. The other gear is mounted so as to turn independently from its pitch-circle disc. The known motions of the two pitch-circle discs are used to test the unknown motion produced by the gear teeth when mating. If the involute curves are correct and the spacing of the teeth is uniform, a gear should go on the angular-velocity fixture and show no deviation in motion. It should also go on the vernier machine without showing any jump per tooth. A jump per tooth of several thousandths of an inch on the vernier machine will be somewhat more than that when translated into angular motion. When a gear having 60 teeth is running at 1000 r.p.m., there will be 60,000 accelerations and retardations per min. and this may be one of the reasons why gears make noise.

We believe that no gear manufacturer will go wrong if he provides himself with testing instruments that will enable him to know actually what results he is getting in his gears, hobs and machines, and that such instruments will help him to obtain a uniform product. This should be the aim of every gear manufacturer. It will enable him to reduce the gear business to at least a semi-scientific basis. In the past the gear manufacturer, not having any instruments for correctly checking them, has never known what his gear-tooth contours were.

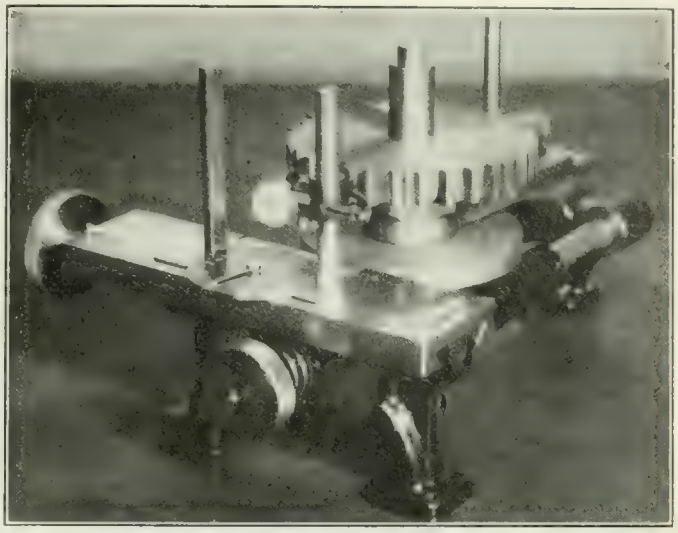


Fig. 13—Machine for Testing Involute Gears

THE DISCUSSION

Rex C. Darnell:—Is it possible to have the proper shape of bearing when grinding two teeth together; for instance, when lapping compounds are put between gears that are running, will the shape of the bearing be correct?

S. O. Bjornberg:—If a lapping compound were put between two gears that were originally inaccurate, they would tend to wear or remain inaccurate. Although the surfaces would lap rather smooth, there is no assurance that those surfaces would automatically become true involute curves, which is one of the geometrical laws that must be fulfilled in gearing. With two surfaces and a high line-bearing on them between the gear teeth, the high bearing might lap down somewhat but it will tend to lap a hollow in the mating gear-tooth; so, there is no assurance of getting correct contours by the lapping process.

A Member:—In my experiments along that line I did the lapping by going a little farther than trying to remove the high spots. I used a certain screw-thread comparator. In that way I have been able to rotate the gears together and, by doing so, I found that, where

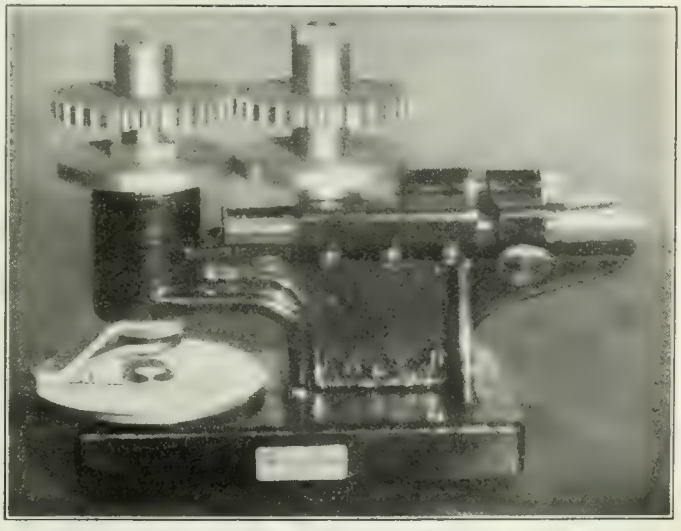


Fig. 14—An Angular-Velocity Testing-Machine for Gears

there is a high spot, the tendency with gears having an equal number of teeth is to wear a hollow right at that high spot.

A MEMBER:—In producing a ground gear, if the contour of the wheel is correct, you should get smooth action. Is it not found that just as good a result is had from a straight-tooth gear as from a helical gear, so far as quietness, wear and accuracy are concerned? What I mean is that, if a ground gear has straight teeth instead of helical or spiral teeth, we should be able to get results just as good as or better than we get with the helical gear; in other words, the ground tooth does away with the need of using helical gears.

R. S. DRUMMOND:—A simple design of gear-tooth form such as plain spur, or plain bevel, when ground to accurate tooth-form, should be as quiet as any shaped tooth can be. We have ground plain-bevel rear-axle gears and made them quiet; and we have ground plain spur gears for front-end gears and made them quiet, more quiet than the normal chain or spiral-bevel drives.

K. L. HERRMANN:—I wish there were some standard of quietness, or some measure of the amount of noise in gearing, so that the subject could be dealt with intelligently.

MR. DRUMMOND:—With reference to varying degrees of quietness, I, too, wish that we had a standard of noise. There is an element in a train of gears that introduces a sing of high pitch based entirely on the relative number of teeth, but this element can be distinguished from the hum of the metal contact between two gears that are running with insufficient oil-clearance, or are dry. It can be differentiated also from the growl that is introduced into even one pair of gears by incorrect tooth-form, and from the marbly rattle when one tooth does not carry over to the next with permanent contact, as frequently occurs with small numbers of teeth that are stubbed off.

A MEMBER:—In dressing the grinding wheel, do you use the same form to generate the gear-tooth that is used for the ordinary rack?

MR. DRUMMOND:—The gear-tooth form is made on a wheel from a similar gear-tooth form of larger size. We can reproduce whatever shape the enlarged template has.

W. F. ZIMMERMAN:—We have the same trouble with gears that everybody else has, particularly in trying to make a machine that will fulfill all the requirements that are now being shown up by the testing instruments that have been developed recently. We have used some of these instruments to test machines in our own shop, and have found various parts that needed attention. One of the great troubles of hobbing machines seems to be due to slight eccentricities in the gearing which are multiplied by the change-gears that are necessary for cutting different numbers of teeth. We have made diagrams which show that the inaccuracy is related to the number of teeth on a gear; that is, for each given number of teeth, there are a high and a low point on the diagrams. If there are no inaccuracies, we ought to get a continuous curve that is generally obtained by eliminating the change-gear trouble.

A considerable amount of trouble of this sort was encountered during the war when we had occasion to furnish a number of large machines for turbine gears, that run at 3600 r.p.m. These gears must run quietly and have a good bearing. Their faces were very wide; some were as wide as 72 in. Considerable trouble was experienced with "spotted bearings." This spotted bearing was in a reverse spiral on the gears, and we could not calculate it back into the gear train of the machine. Later, we found that most of this trouble was due to wrong adjustments, and that this reverse spiral was due to an improperly adjusted cutter spindle. Another trouble was due to an improper adjustment on the index worm, and still another was due to the end-thrust on the feed screw. The last mentioned cause can be measured on the gear very readily.

The wide turbine gears gave us considerable trouble in getting a good bearing across the entire face. Some of the manufacturers used laminated gears so as to avoid the uneven pressure and thereby provide a means for certain portions of the gear teeth to give under heavy leads and compensate for and equalize the pressure across the entire width of face. Extreme accuracy was required, and close attention was paid to the mounting of the gear so that it would be cut concentric with the axis of rotation.

After each blank was removed from the machine, the fixture was again trued and the blank set very carefully for concentricity. In the General Electric Co. shops, by careful attention as outlined, they were able to produce gears that needed lapping or running-in for about 1 day; whereas it required 1 week to lap-in some of the other gears.

As to lapping-in methods, gears generally have a very decided hollow on the pitch-line after being lapped, particularly those gears that have to be lapped for a week. Some of those wide gears were cut with multiple-thread and some with single-thread leads. It was found that the single-thread lead constituted the better proposition.

One of the great troubles in the gear machines has been the difficulty of obtaining concentricity of the gears produced, which is oftentimes confused with inaccurate spacing.

T. J. LITLE, JR.:—Does Mr. Drummond think that with careful grinding of the drive-gears in the front end of the engine he could cause the operation to be as silent as that of the silent chain?

MR. DRUMMOND:—It is possible to produce ground gears for the front-end drive that are commercially quiet. A large amount of noise introduced into the front-end gears actually is produced in other parts of the mechanism, such, for instance, as that due to an unbalanced shaft. Such noise cannot be ground out, but the noise that is due solely to gear operation can be satisfactorily ground out. Years ago front-end drive spur-gears were made without hardening and were quiet. This effect was secured by using extreme care and accuracy in the cutting.

To carry out the same idea, not only are front-end gears made quiet by grinding in the simple spur-gear design, but also ordinary plain bevel-gears in rear axles have been made to operate quietly by grinding out the distortion of the teeth. In former times we have seen plain bevel-gear axles that were quiet when made very accurately as to tooth-form.

Part of the interest in spiral bevel-gears is due to the need of eliminating noise. In different factories we find to-day that there is the same sort of noise and about the same amount of trouble in the later spiral designs that there was in the earlier ones, because of the bad shape of the teeth. Similarly, in the front-end drive, efforts have been made toward changing the material and the design of the teeth and introducing special-shaped teeth to eliminate the noise; but many factories using these peculiar methods are still troubled with the noise.

We should approach the problem of gear noise rather with a view to making the tooth-form as accurate as possible than to changing the design and the shape of the

teeth. It is better to use properly made spur gears than to use spiral gears, helical gears, gears made by the shaping method or chains.

If accurately cut gears are run together with a lapping compound, both gears will be ruined just as a plain shaft and a bearing would be ruined by putting emery on them.

MR. DARNELL:—With regard to how great the backlash should be, a statement was made that it might be as high as 0.03 in., but that seems to be entirely contrary to any experience that we have had. We made some calculations recently of what the reactions on the camshafts are and, taking the resultant of all forces involved, found certain peaks. We figured that we would be likely to get the most difficulty due to high backlash at a low speed and, particularly in truck engines when running with a wide-open throttle, some torsional vibration in the crankshaft is bound to occur. Further investigation proved that where the maximum reaction occurred on the camshaft, the greatest torsional vibration was shown on the crankshaft and this produced an extreme rattle. Consequently, we had to abandon the use of backlash that exceeded 0.005 in.

MR. HERRMANN:—I believe the backlash amounting to 0.030 in., referred to in our discussion, has been in connection with transmission and sliding gears.

MR. DRUMMOND:—The large amount of backlash referred to is in transmission gears, not in front-end gears. The backlash in front-end gears should be held within very close limits.

L. A. DANSE:—It is possible to heat-treat gears that are well cut so that they will mate pretty well afterward. We do not feel we are entirely beyond getting some help from the grinders, but we feel that with commercial accuracy in the cutting and ordinary care in the heat-treating, we will get commercial accuracy and a good match in the finished product and not have to resort to excessive lapping. We used to practise this lapping, and some of our gear lapping occasionally ran as high as 40 min. Our gear men now feel that if they have to run over 4 or 5 min. to clean up the teeth, it is better to scrap the gear. They think it is certain that inaccurate gear contour will result after that much lapping. In fact, our lapping time does not exceed 1.5 min.

A MEMBER:—There seems to be an impression on the part of many engineers and manufacturers that the silent-chain front-end drive is an expensive installation, and it has not been adopted for that reason. They forget that the front-end drive sometimes consists of three sprockets and chains, and that they are costly. The trouble that is experienced with gears in the average plant is not taken into consideration as compared with the cost of the permanent chain or the troubles they have with it. The noise in the front end is not always due to the gear design or to the front-end chain-design layout, but sometimes to the loading of the accessory shaft. The fact that some manufacturers have a very successful gear-drive as well as a chain-drive, while other manufacturers have trouble, although perhaps they are producing just as accurate work, is accounted for by their looking into the conditions of loading under which the gears operate. It often has been found that the difference between the loading conditions of two engines accounts for the difference in the amount of noise the engines make.

Another cause of noise in the gears as well as in the chain is crankshaft vibration. It has been proved very often that by eliminating vibration, particularly the torsional vibration, the chain noise is reduced and sometimes eliminated.

MR. HERRMANN:—There are two extremes of gear error; one causes a singing sound and the other causes a rattle. Has anyone been able to trace definitely the causes of the rattle and the singing and the causes of the intermediate steps? The rattle apparently occurs just a little too fast for the ear to detect the individual blows. Some ears can detect the individual blows at 15 vibrations per sec., while other ears are more sensitive and can detect the individual blows at 30 vibrations per sec. The higher-pitched tone or howl may correspond to tones ranging from 100 to 500 vibrations per sec. In a transmission the question is, just how much of the noise is due to gear-tooth form and how much to spacing error or other causes? I have heard indirectly that some very interesting experiments were made in this connection about 6 years ago.

A MEMBER:—I conducted some tests that indicate that the intensity of sound and the degree of pitch are in direct proportion to the number of teeth in contact. At the normal rotating speed, the indication is for a higher pitch when more teeth are in contact.

BENZENE AS ENGINE FUEL

MOTOR benzene is obtained as a coke-oven by-product. It conforms approximately to the following specifications: Distillation, first drop, 79.4 deg. cent. (174.9 deg. fahr.); 60 per cent, 100.0 deg. cent. (212 deg. fahr.); 90 per cent, 135 deg. cent. (275 deg. fahr.); residue, none. It must be neutral, containing no foreign substances except slight quantities of sulphur present as carbon bisulphide or thiophene to total approximately 0.25 per cent. Its specific gravity at 15.5 deg. cent. (60 deg. fahr.) is 0.878.

A distillation test of a high-grade motor gasoline compares with this as follows: First drop, 57 deg. cent. (134.6 deg. fahr.); 20 per cent, 100 deg. cent. (212 deg. fahr.); 60 per cent, 142 deg. cent. (287.6 deg. fahr.); 90 per cent, 197 deg. cent. (386.6 deg. fahr.); 93.5 per cent, or dry, 214 deg. cent. (417.2 deg. fahr.). The residue is 0.2 per cent and the specific gravity at 15.5 deg. cent. (60 deg. fahr.) is 0.732. Tests show that the motor benzene evaporates completely in about one-fifth the time required for the above sample of high-grade gasoline, because of the high end-point of the latter. The calorific value of benzene is 137,000 B.t.u. per gal., as compared with gasoline at 113,500 B.t.u. In an engine test 36 hp. was developed with the benzene as compared to 34.5 under the same conditions by gasoline. The total consumption was 0.109 lb. per b.hp.-hr. for benzene and compared to 0.122 lb. for gasoline, an increase of 10.7 per cent in efficiency in favor of the benzene. Moreover, the engine ran more smoothly on benzene, less carbon was deposited on the pistons and the cooling water was not so hot. Proper distillation of the benzene eliminates practically all the sulphur compounds, and so does away with corrosion troubles when this fuel is used.—W. O. Hinckley in *Chemical Abstracts*.

Tractor Industry in 1922[1]

By O. W. Young[2]

DURING the year 1922 the tractor industry has experienced a considerable revival of activity from the extreme depression of the previous year. While production has been very limited, in most cases, the liquidation of inventories so burdensome during last year has been accomplished largely and an optimistic attitude as to the future is becoming apparent throughout the industry. From available export figures, foreign trade appears to have been as low as any year since 1917, if not lower, due principally to low exchange-values.

Definite improvement has been evident during the last quarter of 1922 toward readjusting the balance of values of farm products with other commodities required on the farm. The farm credit-situation also has shown improvement. The effect of these changes already has been felt in increased interest in power farming and in reviving tractor sales in many lines. Prospects for continued improvement in this direction are very bright for the coming year.

Mechanical equipment on our farms is to a great extent depleted and worn out; it needs replacement and it is anticipated by some manufacturers that the demands for most types of farm equipment this year will exceed production, as estimated at present. It is felt, generally, that tractor prices will need to be advanced from the low and unprofitable levels prevailing during the past year.

Despite conditions, the power-farming idea has progressed this year in the esteem of the farmer. As evidence of this, it is significant that a considerable number of small two-plow tractors have been produced and sold during the year. While this perhaps is due mainly to the very low prices, nevertheless these units contribute toward popularizing power farming when put into the field. They usually represent initial purchases and, in the majority of cases, lead to a demand for larger and more efficient units, from the standpoint of labor cost in operation. While the general-utility and horse-replacement value of these small conventional units is limited, the low prices at which they were sold more than justified their purchase to expedite field work, handle peak loads and provide power for belt work.

During this period of restricted production, time has been put to good use in the development of new designs of various types and in important detail refinement. Much thought and experimental work have been directed toward the development of types providing for a wider utility range, especially for the handling of all operations pertaining to row crops. Considerable progress has been made toward a more general appreciation of the requirements of a general-purpose type. Also, new models of conventional type and refined construction have been developed and important improvements introduced in current models. Progress has been made in increased engine efficiency, due principally to improvements in fuel vaporization and in mechanical refinement.

TRACTOR DESIGN FUNDAMENTALS

Certain fundamentals of tractor design are becoming established more clearly. The general trend has been to somewhat higher ratios of power to tractor weight, and to decreased ratios of weight to drawbar performance. The increased power-weight ratios usually are obtained more in weight reduction than in power increase, the tendency being to limit the drawbar performance by weight and traction rather than by power; also to operate the engines at a more efficient power-range and in many cases with greater reserve. With decreased weight, it is becoming increasingly important to continue to improve the effectiveness of grouter and lug equipment, and possibly to develop other effective traction devices.

Important development work has been done on more efficient harvesting equipment of various types, and this will enhance power farming in some directions.

General progress in standardization this year can be said to be represented in the increased use of existing S.A.E. Standards in new designs, rather than in the formulating of new standards. The Society's exhibit at the National Tractor Show in February, 1922, did much to point out the value of S.A.E. Standards. It showed the surprising extent to which they are already applied in tractors, especially in engine details and fittings, materials, shaft splines, bearings and the like. A continuation of this educational feature in future tractor shows should be of value to stimulate greater interest in, and availing of, the Society's Standardization work.

Advance is being made in more logical and simplified standards for tractor belts, belt speeds and pulleys; ratings and test forms also are receiving thorough consideration and very likely will be ready for definite action during the coming year.

TWO PHASES OF TRACTOR ENGINEERING

Tractor engineering at this time can be said to present two major phases. One covers all the detail mechanical problems, from fuel utilization and engine and transmission design to the development of traction members, and includes the refinement and perfection of established conventional tractors. The other major phase has as its objects the extension of power application to all of the field operations of diversified farming, and centers in the development of a general-purpose type or types. Unquestionably, herein lies the greatest opportunity and most important problem before the tractor industry, the solution of which holds rich rewards.

The general performance specifications that an all-purpose tractor would be required to meet have been variously defined, but opinions agree on the broad essentials. The great possibilities of such a type, with reference to horse-replacement and labor-saving, and the immense potential market, certainly provide a fruitful field of endeavor for the engineering talent of the industry.

[1] Annual report of the Second Vice-President representing tractor engineering.

[2] M.S.A.E. Engineering manager, Hyatt Roller Bearing Co., Chicago.

Personnel of 1923 Standards Committee

THE designation of the Standards Committee personnel for this year has been completed, the Council having again taken action considerably earlier than in the years previous to 1922. The prompt formation of the 1923 Divisions will enable them to begin active work soon.

The Standards Committee for 1923 will be constituted of 27 Divisions. It is believed that these will form in the main a permanent group some one or more of which can be assigned practically any subject that the Council may approve for consideration in connection with standardization. Some of the Divisions will, of course, be more active than others at certain times. The total number of members of the committee will be about 15 per cent greater than that of last year and almost 35 per cent more than in 1921.

STANDARDS COMMITTEE

E. A. Johnston, *Chairman*
C. M. Manly, *Vice-Chairman*
G. W. Dunham, *Vice-Chairman*

AERONAUTIC DIVISION

H. M. Crane, *Chairman*	Consulting Engineer
G. J. Mead, *Vice-Chairman*	Wright Aeronautical Corporation
Porter H. Adams	National Aeronautic Association of U. S. A.
A. F. Arcier	Wittemann - Lewis Aircraft Co., Inc.
V. E. Clark	Dayton-Wright Co.
W. L. Gilmore	Curtiss Engineering Co.
L. M. Griffith	National Advisory Committee for Aeronautics
J. L. Harkness	L. W. F. Engineering Co.
E. T. Jones	Air Service
Lieut. B. G. Leighton	Navy Department
G. C. Loening	Loening Aeronautical Engineering Corporation
R. G. Page	Air Mail Service
Com. H. C. Richardson	Naval Aircraft Factory
W. T. Thomas	Consulting Engineer
R. H. Upson	Aircraft Development Corporation.
Edward Wallace	Glenn L. Martin Co.
L. M. Woolson	Packard Motor Car Co.

AGRICULTURAL POWER EQUIPMENT DIVISION

C. B. Rose, *Chairman*	Moline Plow Co.
A. W. Scarratt, *Vice-Chairman*	Minneapolis Steel & Machinery Co.
J. B. Bartholomew	Avery Co.
C. E. Frudden	Hart-Parr Co.
A. H. Gilbert	Rock Island Plow Co.
R. O Hendrickson	J. I. Case Plow Works Co.
Pliny E. Holt	Holt Mfg. Co.
John Mainland	Advance-Rumely Co.
M. B. Morgan	Timken-Detroit Axle Co.
J. F. Max Patitz	Allis-Chalmers Mfg. Co.
O. W. Sjogren	University of Nebraska
L. W. Witry	Waterloo Gasoline Engine Co.
G. A. Young	Purdue University
O. W. Young	Hyatt Roller Bearing Co.
O. B. Zimmerman	International Harvester Co.

AXLE AND WHEELS DIVISION

C. C. Carlton, *Chairman*	Motor Wheel Corporation
C. S. Dahlquist, *Vice-Chairman*	Eaton Axle Co.
R. S. Begg	Jordan Motor Car Co.
T. V. Buckwalter	Timken Roller Bearing Co.
R. J. Burrows	Clark Equipment Co. (Also representing Motor and Accessory Manufacturers' Association)
L. W. Close	Bock Bearing Co.
J. Coapman	Russel Motor Axle Co.
H. E. Derr	International Harvester Co.
G. W. Dunham	Savage Arms Corporation
F. W. Gurney	Gurney Ball Bearing Co.
F. P. Hall, Jr.	Salisbury Axle Co.
G. W. Harper	Columbia Axle Co.
George L. Lavery	West Steel Casting Co.
A. M. Laycock	Sheldon Axle & Spring Co.
H. V. Ludwick	Budd Wheel Corporation.
C. T. Myers	Consulting Engineer
A. L. Putnam	Detroit Pressed Steel Co.
O. J. Rohde	Wire Wheel Corporation of America
F. A. Shuler	Shuler Axle Co.
Frank Spring	Courier Motors Co.
H. Vanderbeek	Formerly with Timken-Detroit Axle Co.

BALL AND ROLLER BEARINGS DIVISION

F. W. Gurney *Chairman*	Gurney Ball Bearing Co.
T. V. Buckwalter, *Vice-Chairman*	Timken Roller Bearing Co.
J. T. R. Bell	Railway Roller Bearing Co.
G. R. Bott	Norma Co. of America
H. E. Brunner	S. K. F. Industries, Inc.
E. R. Carter, Jr.	Fafnir Bearing Co.
D. F. Chambers	Bearings Co. of America
L. W. Close	Bock Bearing Co.
L. A. Cummings	Standard Steel & Bearings, Inc.
G. W. Dunham	Savage Arms Corporation.
F. G. Hughes	New Departure Mfg. Co.
G. L. Miller	Gilliam Mfg. Co.
R. G. Schaffner	Bower Roller Bearing Co.
W. R. Strickland	Cadillac Motor Car Co.
R. E. Wells	Hyatt Roller Bearing Co.

ROLLER BEARING SUBDIVISION

F E. Moskovics, *Chairman*	Nordyke & Marmon Co., Inc.
R. S. Begg	Jordan Motor Car Co.
J. T. R. Bell	Railway Roller Bearing Co.
G. R. Bott	Norma Co. of America
T. V. Buckwalter	Timken Roller Bearing Co.
A. C. Bryan	Durston Gear Corporation
L. W. Close	Bock Bearing Co.
G. W. Dunham	Savage Arms Corporation
A. A. Gloetzner	Covert Gear Co., Inc.
M. C. Horine	International Motor Co.
A. M. Laycock	Sheldon Axle & Spring Co.
G. L. Miller	Gilliam Mfg. Co.
R. G. Schaffner	Bower Roller Bearing Co.
L. M. Stellman	H. H. Franklin Mfg. Co.
Andrew Van Halteren	Motor Wheel Corporation
R. E. Wells	Hyatt Roller Bearing Co.

CHAIN DIVISION

H. S. Pierce, *Chairman*	Link Belt Co.
W. J. Belcher, *Vice-Chairman*	Whitney Mfg. Co.
D. B. Baker	International Harvester Co.
W. F. Cole	Baldwin Chain & Mfg. Co.
E. S. Corcoran	Kelly-Springfield Motor Truck Co.
H. F. L. Funke	Herbert F. L. Funke Co., Inc.

M. C. Horine	International Motor Co.
J. C. Howe	American High Speed Chain Co.
F. L. Morse	Morse Chain Co.
W. A. Rockenfield	Baldwin Chain & Mfg. Co.
L. M. Wainwright	Diamond Chain & Mfg. Co.

ELECTRIC VEHICLE DIVISION

E. L. Clark, *Chairman*	Commercial Truck Co.
Karl Probst, *Vice-Chairman*	Milburn Wagon Co.
G. L. Bixby	Detroit Electric Car Co.
A. K. Brumbaugh	Autocar Co.
J. G. Carroll	Walker Vehicle Co.
Hugh M. Pierce	Ward Motor Vehicle Co.
F. E. Queeney	Lansden Co., Inc.
Charles R. Skinner, Jr.	New York Edison Co. (Also representing National Electric Light Association)

ELECTRICAL EQUIPMENT DIVISION

F. W. Andrew, *Chairman*	Eisemann Magneto Co.
T. L. Lee, *Vice-Chairman*	North East Electric Co.
C. R. Alling	Underwriters' Laboratories.
Azel Ames	Kerite Insulated Wire & Cable Co.
W. A. Chryst	Dayton Engineering Laboratories Co.
S. F. Evelyn	Continental Motors Corporation
C. F. Gilchrist	Electric Auto-Lite Corporation
W. S. Haggott	Packard Electric Co.
F. C. Kroeger	Remy Electric Co.
B. M. Leece	Leece-Neville Co.
A. D. T. Libby	Splitdorf Electrical Co. (Also representing Motor and Accessory Manufacturers' Association)
W. P. Loudon	Westinghouse Electric & Mfg. Co.
Charles Marcus	Bijur Motor Appliance Co.
Ernest Wooler	Cleveland Automobile Co.

ENGINE DIVISION

J. B. Fisher, *Chairman*	Waukesha Motor Co.
R. J. Broege, *Vice-Chairman*	Buda Co. (Also representing Motor and Accessory Manufacturers' Association)
P. J. Dasey	Midwest Engine Co.
S. F. Evelyn	Continental Motors Corporation.
Pliny E. Holt	Holt Mfg. Co.
A. F. Milbrath	Wisconsin Motor Mfg. Co.
Louis Schwitzer	Automotive Parts Co.
M. J. Steele	Packard Motor Car Co.
Joseph VanBlerck	Joseph VanBlerck Engine Corporation
W. C. Ware	Fay & Bowen Engine Co.

FRAMES DIVISION

William A. McKinley, *Chairman*	Detroit Pressed Steel Co.
C. C. Bowman, *Vice-Chairman*	Standard Motor Truck Co.
E. A. DeWaters	Buick Motor Co.
L. J. Fralick	Hydraulic Pressed Steel Co.
O. B. Harmon	Parish & Bingham Co.
Ernest Wooler	Cleveland Automobile Co.

IRON AND STEEL DIVISION

F. P. Gilligan, *Chairman*	Henry Souther Engineering Co.
W. C. Peterson, *Vice-Chairman*	Atlas Steel Corporation
R. M. Bird	Bethlehem Steel Co.
H. T. Chandler	Vanadium Corporation of America
A. L. Colby	Representing American Society for Testing Materials
B. F. Cortwright	Wisconsin Steel Co.
J. B. Dailey	General Motors Corporation
L. A. Danse	Cadillac Motor Car Co.
C. N. Dawe	Studebaker Corporation of America
B. H. DeLong	Carpenter Steel Co.
A. P. Eves	International Harvester Co.
H. L. Greene	Willys-Overland Co.
G. F. Harper	Allis-Chalmers Mfg. Co.
William H. Higgins	Advance-Rumely Co., Inc.
E. J. Janitzky	Illinois Steel Co.
J. B. Johnson	Air Service
F. C. Langenberg	Watertown Arsenal
F. E. McCleary	Dodge Bros.
C. S. Moody	Minneapolis Steel & Machinery Co.
J. H. Nelson	Wyman-Gordon Co.
G. L. Norris	Vanadium Corporation of America
W. H. Phillips	R. D. Nuttall Co. (Also representing American Gear Manufacturers Association)
S. P. Rockwell	Representing American Gear Manufacturers' Association
Mason P. Rumney	Detroit Steel Products Co.
C. F. W. Rys	Carnegie Steel Co.
R. B. Schenck	Buick Motor Co.
M. H. Schmid	United Alloy Steel Corporation
H. J. Stagg	Halcomb Steel Co.
J. M. Watson	Hupp Motor Car Corporation

ISOLATED ELECTRIC LIGHTING PLANT DIVISION

E. B. Newill, *Chairman*	Westinghouse Electric & Mfg. Co.
C. E. Reddig, *Vice-Chairman*	Western Electric Co.
F. C. Barton	General Electric Co.
L. F. Burger	International Harvester Co.
G. M. Gardner	Globe Electric Co.
Bryan T. Hawley	Holt Power Light Co.
L. S. Keilholtz	Delco-Light Co.
Don D. Myers	Electric Auto-Lite Corporation
P. F. Shivers	Webster Electric Co.
F. L. Tubbs	Alamo Farm Light Co.
H. L. Zabriskie	Representing Electric Power Club

LIGHTING DIVISION

W. A. McKay, *Chairman*	Westinghouse Lamp Co.
C. A. Michel, *Vice-Chairman*	Guide Motor Lamp Co.
A. K. Brumbaugh	Autocar Co.
J. T. Caldwell	General Electric Co.
G. P. Doll	Thomas Corcoran Lamp Co.
C. E. Godley	Edmunds & Jones Corporation
C. A. B. Halvorson, Jr.	General Electric Co.
J. H. Hunt	General Motors Corporation
A. R. Lewellen	Chevrolet Motor Co.
H. H. Magdsick	General Electric Co.
W. J. Outcalt	General Motors Corporation
L. C. Porter	Edison Lamp Works
E. S. Preston	Chicago Electric Mfg. Co.
C. D. Ryder	Corcoran-Victor Co.
A. J. Scaife	White Motor Co.
J. C. Stearns	Culver-Stearns Mfg. Co.
F. W. Todd	Accessories Mfg. Co.
Thomas I. Walker	General Electric Co.
E. E. Wood, Jr.	Miniature Incandescent Lamp Corporation
Ernest Wooler	Cleveland Automobile Co.

LUBRICANTS DIVISION

H. C. Mougey, *Chairman*	General Motors Research Corporation
W. E. Jominy, *Vice-Chairman*	Studebaker Corporation of America
Sydney Bevin	Tidewater Oil Co.
P. J. Dasey	Midwest Engine Co.
A. P. Eves	International Harvester Co.
W. H. Herschel	Bureau of Standards
K. G. Mackenzie	Texas Co. (Also representing American Society for Testing Materials)
C. H. Osmund	Atlantic Refining Co.
W. E. Perdew	Union Petroleum Co.
W. D. Reese	Fifth Avenue Coach Co.
Herschell G. Smith	Gulf Refining Co.
J. W. Stack	Standard Oil Co.

MOTORBOAT DIVISION

Irwin Chase, *Chairman*	Elco Works
W. J. Deed	*Motorship*
A. E. Luders	Luders Marine Construction Co.
Q. B. Newman	Coast Guard Service
Leonard Ochtman, Jr.	Joseph VanBlerck Engine Corporation
P. A. Proal	Red Bank Yacht Works
W. A. Roos, Jr.	Consolidated Shipbuilding Corporation
L. H. Thomson	Belle Isle Boat & Engine Co.

MOTORCYCLE DIVISION

C. B. Franklin, *Chairman*	Hendee Mfg. Co.
A. W. Herrington, *Vice-Chairman*	Quartermaster Department
W. S. Harley	Harley-Davidson Motor Co.

NOMENCLATURE DIVISION

H. L. Pope, *Chairman*	Wright Aeronautical Corporation
W. P. Kennedy, *Vice-Chairman*	Kennedy Engineering Corporation
J. B. Bartholomew	Avery Co. (Also representing National Association of Farm Equipment Manufacturers)
W. F. Borgerd	International Harvester Co.
W. S. Bouton	Hendee Mfg. Co.
W. J. Brandon	Avery Co.
H. R. Cobleigh	National Automobile Chamber of Commerce
W. P. Culver	American Auto Parts Co. (Also representing Motor and Accessory Manufacturers' Association)
A. B. Cumner	Autocar Co.
L. S. Keilholtz	Delco-Light Co.
V. E. McMullen	Hercules Corporation
Leonard Ochtman, Jr.	Joseph VanBlerck Engine Corporation
W. T. Thomas	Thomas-Morse Aircraft Corporation
L. C. Voyles	Nordyke & Marmon Co.
L. M. Woolson	Packard Motor Car Co.

NON-FERROUS METALS DIVISION

Zay Jeffries, *Chairman*	Aluminum Co. of America
W. R. Webster, *Vice-Chairman*	Bridgeport Brass Co.
A. G. Carman	Franklin Die-Casting Corporation
D. L. Colwell	Stewart Mfg. Co.
G. K. Elliott	Lunkenheimer Co.
John R. Freeman, Jr.	Bureau of Standards
E. S. Fretz	Light Mfg. & Foundry Co.
Albert J. Hall	General Motors Corporation
H. C. Mougey	General Motors Research Corporation
W. B. Price	Scovill Mfg. Co.
G. C. Rauhauser	Denby Motor Truck Co.
Sam Tour	Doehler Die-Casting Co.
T. H. Wickenden	International Nickel Co.

PARTS AND FITTINGS DIVISION

W. C. Keys, *Chairman*	Gabriel Snubber Sales & Service Co.
Clarence Carson, *Vice-Chairman*	Dodge Brothers
C. R. Alling	Underwriters' Laboratories
H. B. Garman	Garman Mfg. Co.
H. S. Jandus	C. G. Spring Co.
W. J. Outcalt	General Motors Corporation
F. W. Slack	Peerless Motor Car Co.
C. W. Spicer	Spicer Mfg. Corporation
E. W. Weaver	Weaver & Kemble Co.
F. G. Whittington	Stewart-Warner Speedometer Co.

PASSENGER CAR DIVISION

R. S. Begg, *Chairman*	Jordan Motor Car Co.
L. A. Chaminade, *Vice-Chairman*	Studebaker Corporation of America
Ralph C. Chesnutt	Templar Motor Car Co.
G. B. Sayre	Saxon Motor Car Co.
L. M. Stellmann	H. H. Franklin Mfg. Co.
J. H. Tuttle	Westcott Motor Car Co.
W. G. Wall	National Motor Car & Vehicle Corporation.

PASSENGER-CAR BODY DIVISION

A. J. Neerken, *Chairman*	Hupp Motor Car Co.
G. J. Mercer, *Vice-Chairman*	Consulting Engineer (Also representing Automobile Body Builders' Association)
E. J. Bartlett	Baker R & L Co. (Also representing Automobile Body Builders' Association)
R. E. Brown	Fisher Body Co.
Kingston Forbes	Buick Motor Co.
E. J. Connelly	Wilson Body Co.
A. E. Garrels	Studebaker Corporation of America
G. E. Goddard	Dodge Bros.
E. W. Goodwin	Maxwell Motor Corporation
R. A. LaBarre	Anderson Electric Car Co.

RADIATOR DIVISION

J. D. Harris, *Chairman*	McCord Mfg. Co., Inc.
James A. White, *Vice-Chairman*	Harrison Radiator Co.
H. A. Higgins	Long Mfg. Co.
H. B. Knap	Packard Motor Car Co.
Charles Oppe	G. & O. Mfg. Co.
C. T. Perkins	Modine Mfg. Co.
G. H. Pettit	Atterbury Motor Car Co.
S. W. Rushmore	Rushmore Laboratory
H. M. Yeager	Fedders Mfg. Co.
Fred M. Young	Perfex Radiator Co.
John G. Zummach	Zummach Engineering Service

SCREW-THREADS DIVISION

E. H. Ehrman, *Chairman*	Chicago Screw Co.
O. B. Zimmerman, *Vice-Chairman*	International Harvester Co.
Mr. Bradford	International Harvester Co.
Earle Buckingham	Pratt & Whitney Co.
E. Burdsall	Russell, Burdsall & Ward Bolt & Nut Co.
Luther Burlingame	Brown & Sharpe Mfg. Co.

G. S. Case	Lamson & Sessions Co.
William R. Mitchell	National Acme Mfg. Co.
Alex Taub	General Motors Corporation

SPRINGS DIVISION

S. P. Hess, *Chairman*	Detroit Steel Products Co.
H. R. McMahon, *Vice-Chairman*	Standard Steel Spring Co.
R. S. Begg	Jordan Motor Car Co.
E. S. Corcoran	Kelly-Springfield Motor Truck Co.
Wayne E. Dunston	C. G. Spring Co.
H. E. Figgie	Standard Steel Spring Co.
W. M. Newkirk	William & Harvey Rowland, Inc.
Gustaf Peterson	Atlas Steel Corporation
E. V. Rippingille	Watson Stabilator Co.
F. A. Whitten	General Motors Truck Co.

STATIONARY-ENGINE DIVISION

L. F. Burger, *Chairman*	International Harvester Co.
C. B. Segner, *Vice-Chairman*	Domestic Engine & Pump Co.
H. G. Holmes	Novo Engine Co.
V. E. McMullen	Hercules Corporation
I. J. Nelson	Nelson Bros.
T. C. Menges	Associated Manufacturers Co.
O. A. Powell	Cushman Motor Works
L. W. Witry	Waterloo Gasoline Engine Co.

STORAGE-BATTERY DIVISION

I. M. Noble, *Chairman*	Consulting Engineer
W. E. Gossling, *Vice-Chairman*	Prest-O-Lite Corporation
G. L. Bixby	Detroit Electric Car Co.
A. K. Brumbaugh	Autocar Co.
R. N. Chamberlain	Gould Storage Battery Co.
E. L. Clark	Commercial Truck Co.
Bruce Ford	Electric Storage Battery Co.
S. C. Harris	New York Edison Co.
W. E. Holland	Philadelphia Storage Battery Co.
C. T. Klug	Willard Storage Battery Co.
R. C. Mitchell	Edison Storage Battery Co.
J. L. Rupp	Westinghouse Union Battery Co.
G. W. Vinal	Bureau of Standards

TRANSMISSION DIVISION

A. C. Bryan, *Chairman*	Dursten Gear Corporation
L. C. Fuller, *Vice-Chairman*	Fuller & Sons Mfg. Co.
A. W. Copland	Detroit Gear & Machine Co.
D. E. Gamble	Borg & Beck Co.
A. A. Gloetzner	Covert Gear Co., Inc.
Joseph Jandesek	Formerly with Olds Motor Works
W. C. Lipe	Brown-Lipe Gear Co.
Walter M. Petty	Service Motor Truck Co.
C. E. Swenson	Mechanics Machine Co.
S. O. White	Warner Gear Co.
E. E. Wemp	Long Mfg. Co.

TRUCK DIVISION

A. J. Scaife, *Chairman*	White Co.
J. R. Coleman, *Vice-Chairman*	Selden Truck Corporation
A. K. Brumbaugh	Autocar Co.
H. E. Derr	International Harvester Co.
A. W. Herrington	Quartermaster Department
M. C. Horine	International Motor Co.
E. A. Kingsbury	Sanford Motor Truck Co.
H. B. Knap	Packard Motor Car Co.
J. A. Kraus	Garford Motor Truck Co.
Walter M. Petty	Service Motor Truck Co.
F. A. Whitten	General Motors Truck Co.

TENSILE PROPERTIES OF LOW-CARBON STEEL

FOR some time past a study has been in progress in the metallurgical laboratories of the Bureau of Standards on the properties of various grades of boiler plate through the range of from 20 to 465 deg. cent. (68 to 869 deg. fahr.). This has been conducted to determine the effects of blue and cold work, variations in the rate of loading and elastic overstrain and the subsequent behavior of the overstrained steel with time. The results of this work have been published in Technologic Paper No. 219 which describes the special apparatus employed for making high-temperature tensile tests and the differences in behavior of the steel that were noted in the various temperature ranges.

It was found that the proportional limit of the several grades of plates does not decrease with the first rise in temperature but is either maintained at about room temperature value or increases before the final decrease occurs. The increased strength produced by rolling cold or at blue heat, 300 deg. cent. (572 deg. fahr.), is maintained throughout a considerable temperature range, but these effects may be removed by suitable annealing. A high proportional limit exists while tempering cold-rolled plate at 300 deg. cent. (572 deg. fahr.) or after cooling to room temperature, an effect that can be used to advantage in the production of cold-finished products, such as thin-wall seamless steel tubes where bluing after the final cold-pass will produce a high elastic ratio.

Some effects of tensional elastic overstrain are also described in detail. Among the tests made are those showing that the proportional limit can be made to approximate the tensile-strength by overstraining successively at blue heat with gradually increasing loads. Differences in the behavior of overstrained steel upon etching are observed depending upon whether the overload is applied above 465 deg. cent. (869 deg. fahr.) or below blue heat, 300 deg. cent. (572 deg. fahr.). Likewise, the effect of a decrease in the rate of loading is different in these two temperature ranges, though little variation in tensile properties was observed when tests were performed 30 times as fast as would ordinarily be the case.

The Development of a Modern Service-System

By Don T. Hastings[1]

Chicago Service Meeting Paper *Illustrated with* Charts

THE author states that the word "service" has been and still is the most abused word in the automobile language and enumerates some of the causes of poor service. Good service is then considered as constituting a sales asset. The new attitude toward service is described and the progress of the building-up of a combined flat-rate and piece-work system is outlined.

The flat-rate and the piece-work features are analyzed, inclusive of the methods applied to each and comments upon the results obtained. Records form an all-important part, and these are kept on special forms that are illustrated; the method of their utilization is given in detail. The duties of the different members of the service personnel are specified, and it is shown how the different factors are made to combine and produce service that satisfies the car-owner.

THE word "service" has been the most abused word in the automobile language and, unfortunately, it still is in that position in a great many localities. If one mentions "service" to the average motor-car owner, he immediately visualizes a gloomy picture in which the high points are overcharges, poor work, discourtesy and delays, with a wonderful background of dirt. This picture has been the natural result of conditions which were allowed to exist for years by practically all motor-car dealers. Of course, all of them were not guilty on all the above counts, but some serious criticism was justified of each establishment. The result is that this composite picture was formed in the mind of the public.

Causes of Poor Service

The unsatisfactory service that has been given in the past can be traced to several causes. Many distributors, who were salesmen primarily, have looked on service as a necessary evil; consequently, they have paid little or no attention to it. It has been left to some mechanic to try to get by in fixing-up cars with as little expense to the dealer as possible and no regard whatever for the owner. Another prolific cause of poor service has been ignorance of the product on the part of the dealer, and of its requirements in the way of maintenance. Sheer laziness or inertia has caused these dealers to avoid spending the time and energy required to learn how to take care of cars, and such dealers have no conception of the possibilities of service as a sales asset. Another type of dealer who has helped to bring service into ill-repute is the man whose motto is, "get the money." This type has overcharged owners for work, and has insisted upon payment for it regardless of the justice of the charge or the owner's rights.

The builders of cars themselves have been responsible in a great many cases for the high-price evil, because of the exorbitant figures that they set up as the prices of repair parts. The dealer, of course, could do nothing but accept these figures, although he has followed the builder's example, in many cases, and added a high percentage to the factory price of parts in the guise of a charge for handling, freight, express, and the like. Producers also have been responsible for much of the poor service rendered, because they have not insisted that their distributors and dealers give the proper consideration and study to the service problem. So long as a sales volume was maintained, they have been short-sighted and left it to the individual dealer to decide what he should do with his service. Even among those manufacturers who talk service in a more or less feeble way, there has been a decided lack of the proper supervision and assistance that the average dealer must have if he is to succeed in giving good service without a prohibitive outlay.

Good Service as a Sales Asset

Most manufacturers and dealers have failed to realize that first-class service is one of the best aids to the sales department that it is possible to secure. The best advertising is conceded to be the word-of-mouth advertising that a satisfied owner does among his friends and acquaintances. No matter how well satisfied a man is with the car he has purchased, while it is new, he will not remain a booster unless he is able to get satisfactory treatment when in need of adjustments or repairs to his car. The dealer cannot expect orders from the friends of an owner whose standard line of talk is to the effect that his car is fine but that the service rendered by the dealer is poor.

Owners are buying cars more and more on the basis of good service. The average owner would be satisfied to own any one of four or five cars that are in the same price-class, and he is almost certain to inquire about the service given on the various cars before he signs an order. The dealer who has once instituted good service in his establishment is impressed almost daily by the remarks of prospects to the effect that they were rather inclined to buy some competitor's car until some neighbor boosted the dealer's service strongly enough to persuade them to buy one of his cars.

The New Attitude Toward Service

About 5 years ago, a few of the leading dealers in various parts of the Country began to realize that their service departments had not been conducted on the same high plane as had their sales departments. The result was that these few dealers studied the service problem and started to develop this end of their business. Each one, acting independently of the others, consciously or unconsciously adopted the Golden Rule as the goal toward which to strive in their service work. Each one put himself in the place of the individual owner, with the result that they took steps to make their establishments known as having the following service ideals:

[1] M.S.A.E.—Vice-President in charge of service, Williams & Hastings, Inc., Detroit.

(1) A square deal
(2) Courtesy
(3) Cleanliness
(4) Guaranteed work
(5) Reasonable prices
(6) Promptness of delivery
(7) Promises kept when made
(8) An adequate stock of parts

Many of the factories have realized in recent years that unreasonably high parts-prices were proving a handicap in the sale of cars. The result is that many of them now have such a price-list that the total price of all the parts or assemblies required to form a complete car equals or is less than the price of a complete new car.

Among the steps that have been taken looking toward the accomplishment of the ideals mentioned, perhaps the most important is the establishment of flat-rate or guaranteed charges for labor covering the various operations required in the repair of cars. Some of these flat-rate systems have been developed by individual dealers, and others have been prepared by the factories and transmitted to their dealers. It is much more satisfactory to the owner to be told, before the work is started on his car, exactly what the labor charge will be for the various operations required, than it is for him to come in when the work is completed, and find the bill far larger than he had anticipated. If the owner considers that any flat-rate charge is greater than it should be, he has the opportunity of cancelling his order for the particular work in question before it is started. Consequently, this system avoids the unpleasant arguments that occur all too frequently under the old method of charges for labor. One of the leaders in this work was Percy E. Chamberlain of Denver, whose messages on Flat-Rate and the Lady in White have been heard by hundreds of service managers in the last few years.

A bit of history now appears necessary to make clear what follows. In 1919, Mr. Williams and I arranged to secure the distributor's franchise for the Hupmobile for the lower Peninsula of Michigan, with headquarters in Detroit. Mr. Williams had had some 15 years of selling experience in the motor-car business, and I had been for about 12 years connected with the engineering departments of various motor-car companies. The quarters that we were able to secure were such that it was necessary for us to separate the sales and the service departments. The natural result was that Mr. Williams concentrated his attention on the selling end and I fairly lived with the service division. The word "lived" is used advisedly, because for the next 3 years practically all of my time, not only the days and the evenings, but Sundays and holidays as well, was spent in supervising and developing the service work. The building that we secured early in 1920, when the demand for space was far in excess of the supply, was rather small and extremely dirty; it was very poorly lighted and had been used as a storage garage. The floors were covered from ½ to 1 in. thick with grease and dirt, and the inside of the building was black with soot. As we were starting in with a service policy that covered most of the points listed above, our first big job was to clean house. More than a week was spent in removing the accumulated dirt from the floors alone. The inside of the building was sprayed with white paint, and adequate lights and wall outlets for electric-drill and extension-light connections were installed. Sectional wooden bins for handling parts were constructed and painted, and a preliminary supply of parts was installed. The bins were labeled with the part numbers, and a perpetual-inventory stock-record installed. At the end of a month we had a clean, well-lighted shop and parts department, with the skeleton of an organization, and were prepared to give service.

Our next big problem was to develop an organization through which to give owners courteous, prompt and intelligent service. For several months we went through the grief of trying out various men in the several positions. Finally we found suitable men and got them well started along the lines that we considered necessary in the way of educational development. Practically all of the men thus selected are still with our organization, and they have been given the first opportunities to move into more responsible positions as the organization developed. In connection with the educational program for these men, we sent our shop-foreman and our leading service-salesman to attend a course in shop management at the Young Men's Christian Association school, and paid one-half of the cost of the course.

The Flat-Rate System

Our early analysis of the service problem had convinced us that, ultimately, we would install a flat-rate system of charges for the customer, and that we would also install a piece-work system in the shop. We decided further that our flat-rate charges to the customer should, in the great majority of cases, cover labor only, as any system that attempted to include the cost of parts, lubricants, and the like, as well as labor, could be only an estimate system, instead of a definite statement of costs. The advantages of this flat-rate and piece-work system were summarized briefly as follows:

Advantages for the Car-Owner

(1) He is advised in advance regarding the cost of the job, so far as the labor is concerned
(2) The cost of the work to him is reduced
(3) He gets his car sooner, because it reduces the length of time required to do the work
(4) It eliminates any misunderstandings as to the charge, because this is arranged in advance

Advantages for the Dealer

(5) The cost of performing the work is reduced
(6) The tendency is to make the mechanic more careful; for, if his work is judged unsatisfactory by the foreman and the inspector, he must do the work over at his own expense
(7) More floor-space is created, because the work is performed faster
(8) The number of workmen in the shop is lessened
(9) More jobs are put through the shop in a given time
(10) Disputes over customers' bills are eliminated
(11) It eliminates incompetent workmen
(12) Loafing is done away with
(13) New cars are prepared for delivery in less time, and at a standardized rate

Advantages for the Mechanic

(14) His hourly rate while working is increased
(15) It increases his total monthly earnings
(16) His straight-time work is speeded up, so that he can get back on the contract
(17) The mechanic's dislike for certain jobs is eliminated
(18) It creates in him an inventive genius, and he designs tools to help him accomplish the work in a shorter time

We realized that to install such a system on a logical basis required, fundamentally, a knowledge of the vari-

ous operations required in handling repair work, and also of the average time required for each one of these operations. An analysis was made of the repair operations, and they were divided into 25 groups, each group consisting of a number of operations on a particular unit in the car or covering a certain class of work. The total number of operations listed, including those covering the installation of the more commonly sold accessories, was about 400. As soon as this list was prepared, two lines of work developed; the systematic recording of time and a method of making the operations specific.

The Time-Keeping System

It was necessary that the service-salesman write the instructions for each repair-job in such a way as to segregate the operations required in accordance with this new list. It was necessary also that the time-keeping system be arranged so that accurate time was obtained on each operation. The service-salesmen were perfectly willing to cooperate, but it took some time to educate them to analyze the customers' requirements in terms of our operation list. A consistent study of the list and of various work orders on my part and by the service-salesmen eventually resulted in having the orders written properly. The big stumbling-block was to get the time properly reported by the mechanics. Again a process of education and elimination was resorted to, the trouble-makers in the shop left the organization and the records began to come through in fair shape. A time clock was installed to assist in this work, and it seemed to fit the requirements. The outfit has proved to be very satisfactory, since it has an advantage in that electrically controlled time-stamps, working from the master clock, can be installed at any point in the building.

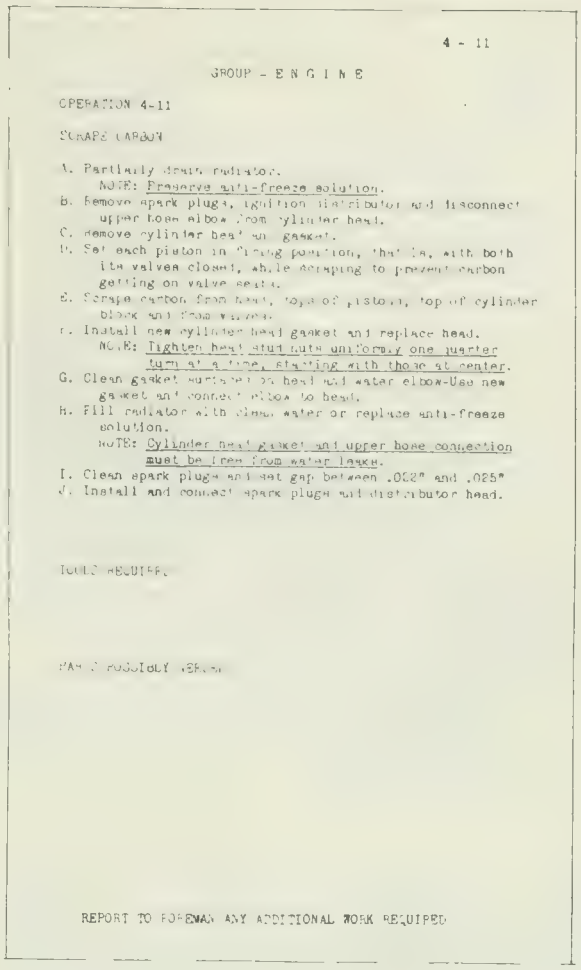
As the time-records accumulated, they were posted to individual sheets for the various operations. These summary sheets were checked over by the shop foreman and myself. Any time-records that were obviously too high or too low were rejected, and the average time required on each operation was determined. In the majority of cases, at least 10 valid reports were used in determining the average; in some cases, the number was more than 100.

Operation Data

It was decided to write-up the detailed procedure required on each operation, so as to

(1) Make definite the work required by each operation
(2) Outline the best procedure to accomplish this work
(3) Inform all mechanics of any shortcuts developed by anyone in the organization
(4) Enable a good mechanic not familiar with this particular car to adapt himself quickly to our particular methods
(5) Avoid the chance of having work ordered by an owner not being completely finished.
(6) Prevent arguments with the mechanics in case their work were incomplete or improperly done, because they must in such case complete it or do it again on their own time

A standard form was adopted for these operation sheets, the original being written on vellum. Carbon paper was used against the back of the vellum so that clear blue-prints measuring 6 x 9½ in., could be made in any quantity required. The working set of these blue-prints for use in the shop was mounted on steel plates, the prints being covered with shellac to preserve them indefinitely. These mounted prints are drawn out on tool checks as required by the workman.



4 - 11

GROUP - E N G I N E

OPERATION 4-11

SCRAPE CARBON

A. Partially drain radiator.
NOTE: Preserve anti-freeze solution.
B. Remove spark plugs, ignition distributor and disconnect upper hose elbow from cylinder head.
C. Remove cylinder head and gasket.
D. Set each piston in firing position, that is, with both its valves closed, while scraping to prevent carbon getting on valve seats.
E. Scrape carbon from head, tops of pistons, top of cylinder block and from valves.
F. Install new cylinder head gasket and replace head.
NOTE: Tighten head stud nuts uniformly one quarter turn at a time, starting with those at center.
G. Clean gasket surfaces on head and water elbow-Use new gasket and connect elbow to head.
H. Fill radiator with clean water or replace anti-freeze solution.
NOTE: Cylinder head gasket and upper hose connection must be free from water leaks.
I. Clean spark plugs and set gap between .022" and .025"
J. Install and connect spark plugs and distributor head.

TOOLS REQUIRED

PARTS FREQUENTLY USED

REPORT TO FOREMAN ANY ADDITIONAL WORK REQUIRED

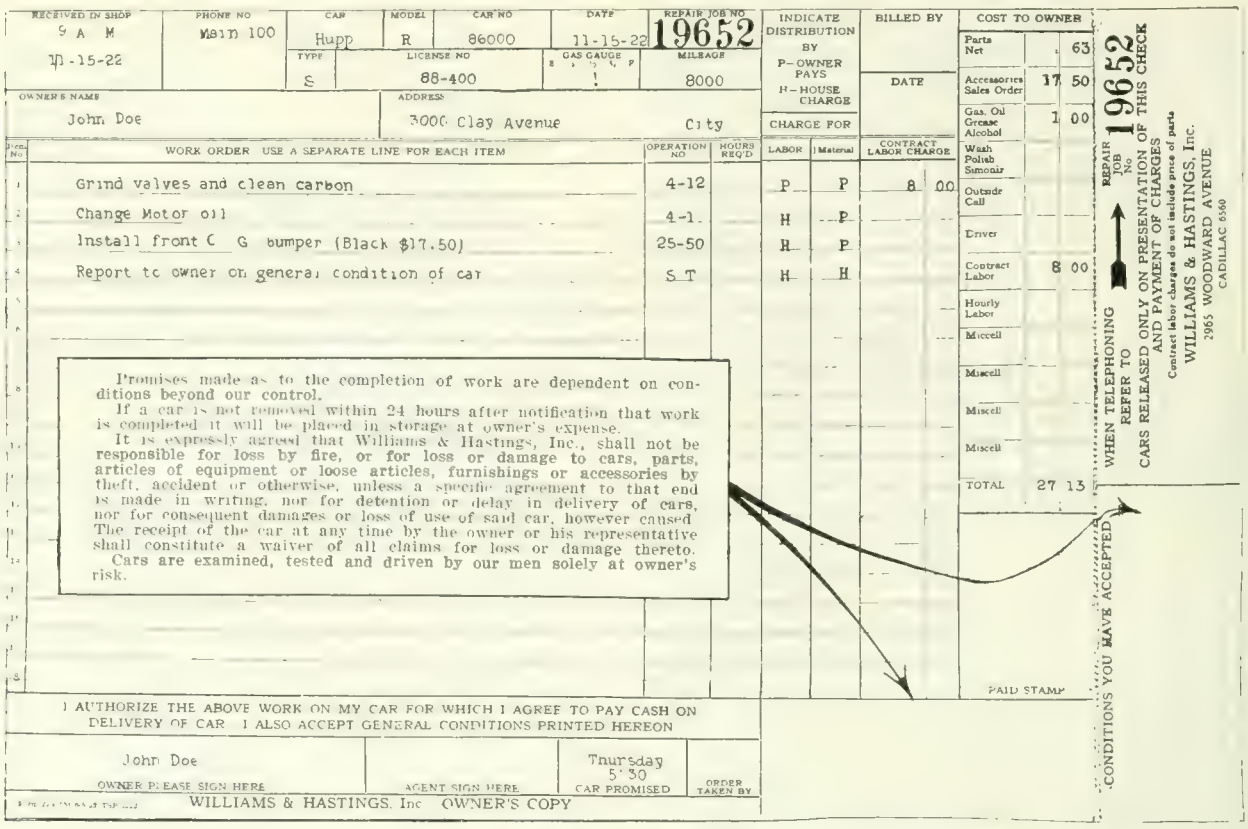
Fig. 1—A Typical Operation Sheet Giving the Various Steps That Are To Be Taken

A typical example of these operation sheets is shown in Fig. 1. The group number and name are stated at the top of this sheet, followed by the operation number and the name of the operation. The operation number is also placed in the upper right-hand corner of the sheet. The detail operations, with the necessary notes, are written in as definite terms as possible. It was found to be a difficult task to put these instructions into such form that they could not be misinterpreted even by the mechanic with little education. A space is provided below the instructions for a list of the special tools required and another space for a list of the parts most commonly required. Neither the tools nor the parts are filled-in on this sample sheet.

At the bottom of each sheet is a standard note: "Report to foreman any additional work rquired." Especial emphasis is laid on this in the shop, as points requiring attention frequently come to the workman's notice, although no mention has been made of them by the owner. Where such additional work is advisable in the judgment of the foreman, an effort is made to get in touch with the owner by telephone, to secure his authorization for the extra work. If it is impossible to reach the owner, the general rule is not to do the additional work; although in some particular cases, where the owner is well known to the service organization, the additional work is done if it is of relatively small amount.

Repair-Job Order-Form

After a process of development had been gone through, the repair-job order-form shown in Figs. 2 to 6 was



RECEIVED IN SHOP 9 A M 11-15-22 | PHONE NO Main 100 | CAR Hupp | MODEL R | CAR NO 86000 | DATE 11-15-22 | REPAIR JOB NO 19652
TYPE S | LICENSE NO 88-400 | GAS GAUGE E ½ F | MILEAGE 8000
OWNER'S NAME John Doe | ADDRESS 3000 Clay Avenue City

Item No	WORK ORDER USE A SEPARATE LINE FOR EACH ITEM	OPERATION NO	HOURS REQ'D	LABOR	Material	CONTRACT LABOR CHARGE
1	Grind valves and clean carbon	4-12		P	P	8 00
2	Change Motor oil	4-1		H	P	
3	Install front C G bumper (Black $17.50)	25-50		H	P	
4	Report to owner on general condition of car	S T		H	H	

INDICATE DISTRIBUTION BY P—OWNER PAYS H—HOUSE CHARGE | CHARGE FOR | BILLED BY | DATE

COST TO OWNER	
Parts Net	63
Accessories Sales Order	17 50
Gas, Oil Grease Alcohol	1 00
Wash Polish Simoniz	
Outside Call	
Driver	
Contract Labor	8 00
Hourly Labor	
Miscell	
Miscell	
Miscell	
TOTAL	27 13

PAID STAMP

Promises made as to the completion of work are dependent on conditions beyond our control.
If a car is not removed within 24 hours after notification that work is completed it will be placed in storage at owner's expense.
It is expressly agreed that Williams & Hastings, Inc., shall not be responsible for loss by fire, or for loss or damage to cars, parts, articles of equipment or loose articles, furnishings or accessories by theft, accident or otherwise, unless a specific agreement to that end is made in writing, nor for detention or delay in delivery of cars, nor for consequent damages or loss of use of said car, however caused. The receipt of the car at any time by the owner or his representative shall constitute a waiver of all claims for loss or damage thereto.
Cars are examined, tested and driven by our men solely at owner's risk.

I AUTHORIZE THE ABOVE WORK ON MY CAR FOR WHICH I AGREE TO PAY CASH ON DELIVERY OF CAR. I ALSO ACCEPT GENERAL CONDITIONS PRINTED HEREON

John Doe (OWNER PLEASE SIGN HERE) | (AGENT SIGN HERE) | Thursday 5:30 (CAR PROMISED) | (ORDER TAKEN BY)

WILLIAMS & HASTINGS, Inc OWNER'S COPY

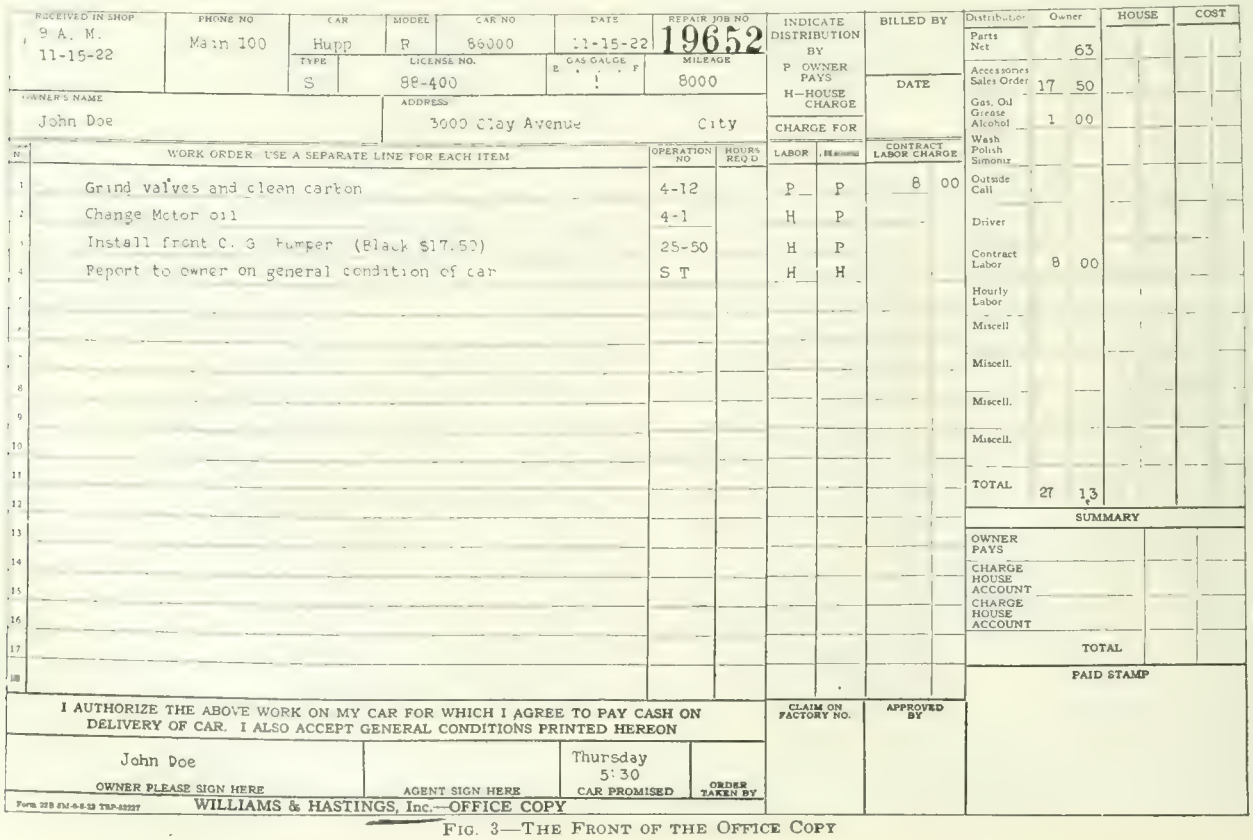
CONDITIONS YOU HAVE ACCEPTED

REPAIR JOB No 19652 WHEN TELEPHONING REFER TO CARS RELEASED ONLY ON PRESENTATION OF THIS CHECK AND PAYMENT OF CHARGES
Contract labor charges do not include price of parts
WILLIAMS & HASTINGS, Inc.
2965 WOODWARD AVENUE
CADILLAC 6560

FIG. 2—THE ORIGINAL OR OWNER'S COPY OF THE REPAIR-JOB ORDER-FORM

finally adopted. This form is printed in quadruplicate. The first sheet, Fig. 2, is the owner's copy; the second, Figs. 3 and 4, the office copy; the third, Fig. 5, the foreman's copy; and the fourth, Fig. 6, the shop copy that is used by the mechanic.

To carry the fourth copy on the car, a celluloid-faced cloth-envelope, open at the top, is provided. This protects the shop copy from grease and dirt while the work is in process. A detailed description of this repair-job order-form will not be attempted here, as the reasons for



RECEIVED IN SHOP 9 A. M. 11-15-22 | PHONE NO Main 100 | CAR Hupp | MODEL R | CAR NO 86000 | DATE 11-15-22 | REPAIR JOB NO 19652
TYPE S | LICENSE NO. 88-400 | GAS GAUGE E ½ F | MILEAGE 8000
OWNER'S NAME John Doe | ADDRESS 3000 Clay Avenue City

No	WORK ORDER USE A SEPARATE LINE FOR EACH ITEM	OPERATION NO	HOURS REQ'D	LABOR		CONTRACT LABOR CHARGE
1	Grind valves and clean carbon	4-12		P	P	8 00
2	Change Motor oil	4-1		H	P	
3	Install front C. G Bumper (Black $17.50)	25-50		H	P	
4	Report to owner on general condition of car	S T		H	H	

INDICATE DISTRIBUTION BY P OWNER PAYS H—HOUSE CHARGE | CHARGE FOR | BILLED BY | DATE

Distribution	Owner		HOUSE	COST
Parts Net		63		
Accessories Sales Order	17	50		
Gas, Oil Grease Alcohol	1	00		
Wash Polish Simoniz				
Outside Call				
Driver				
Contract Labor	8	00		
Hourly Labor				
Miscell				
Miscell.				
Miscell.				
Miscell.				
TOTAL	27	13		

SUMMARY

OWNER PAYS		
CHARGE HOUSE ACCOUNT		
CHARGE HOUSE ACCOUNT		
TOTAL		

PAID STAMP

I AUTHORIZE THE ABOVE WORK ON MY CAR FOR WHICH I AGREE TO PAY CASH ON DELIVERY OF CAR. I ALSO ACCEPT GENERAL CONDITIONS PRINTED HEREON

CLAIM ON FACTORY NO. | APPROVED BY

John Doe (OWNER PLEASE SIGN HERE) | (AGENT SIGN HERE) | Thursday 5:30 (CAR PROMISED) | (ORDER TAKEN BY)

WILLIAMS & HASTINGS, Inc.—OFFICE COPY

FIG. 3—THE FRONT OF THE OFFICE COPY

LABOR

DATE	OPERATION	WORK MAN	TIME	ITEM
		15		
		15		

MATERIAL

Quan.	PART N	NAME	P	H	AMOUNT
1	45215	Water header gasket			03
1	45148	Cylinder head gasket			60

MATERIAL

Quan.	PART N	NAME	P	H	AMOUN

Quan.	ACCESSORIES	P	H	AMOUNT
1	A C 126 C G. Bumper Black			17 50

Quan.	GAS OIL GREASE ALCOHOL	P	H	AMOUNT
1	Gallon cylinder oil			1 00

PURCHASE ORDER	WORK SPECIFIED	COMPANY	P	H	AMOUNT

FIG. 4—THE BACK OF THE OFFICE COPY

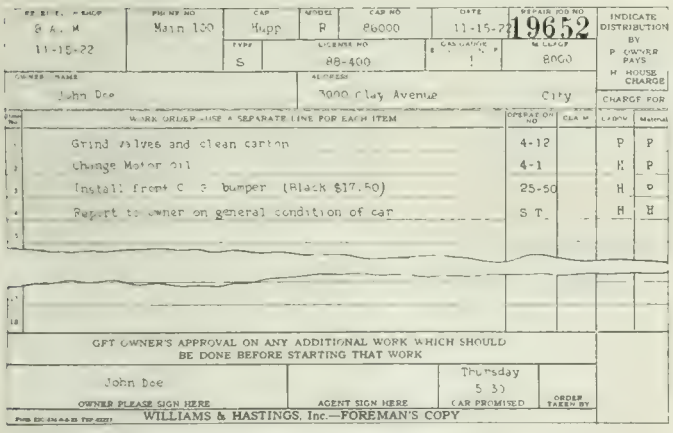


FIG. 5—THE FOREMAN'S COPY

most of the notations are obvious. It probably will suffice to call attention to the claim-check at the right-hand side of the owner's copy, Fig. 2. This sheet is perforated so that the claim-check can be detached readily. In the space on the office copy, Fig. 3, corresponding to the claim-check on the owner's copy, are two columns for house charges and the cost of various items. These two columns carry data that are of no interest to the owner. The back of the office copy, Fig. 4, also carries two columns at the left-hand edge which correspond to the claim-check section of the owner's copy. These two columns provide for the entering of the date and the operation number; consequently, they do not appear on the owner's copy. The time column is not filled-in where an operation is specified, as the charge for any operation is a fixed amount. The time column is used only where straight-time work is done.

The repair-job orders are written-up in pencil, carbon paper being used between the sheets. Typewritten orders look neater, but to typewrite them would require the services of at least one more clerk and seriously delay getting work started and also the completion of the billing on those jobs that are finished at the end of the working day. It will be noted that the foreman's copy and the shop copy of the repair-job order-form are smaller than the other two copies. This is to avoid putting into the hands of the men in the shop information in regard to prices that is of interest only to the owner.

The repair-job order-forms are padded in lots of 25 sheets, and each of the service-salesmen is provided with a light wooden tray into which one of these pads fits. A piece of sheet aluminum, about 1/16 in. thick and the same size as the pad, goes with each one of these trays.

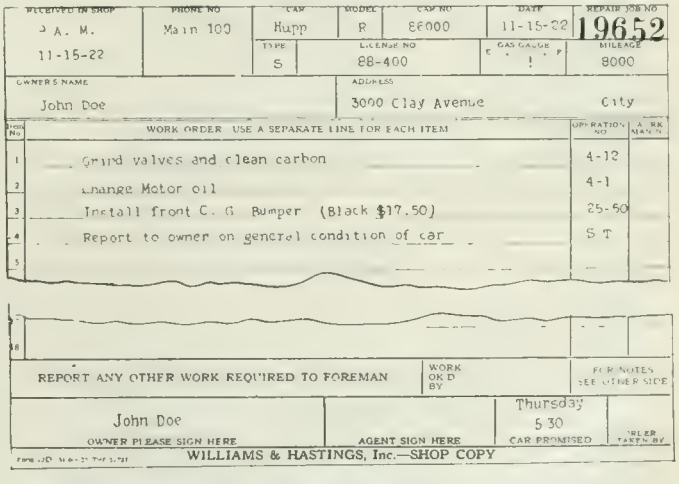


FIG. 6—THE SHOP COPY OF THE REPAIR-JOB ORDER-FORM THAT ACCOMPANIES THE CAR ON ITS PROGRESS THROUGH THE SHOP

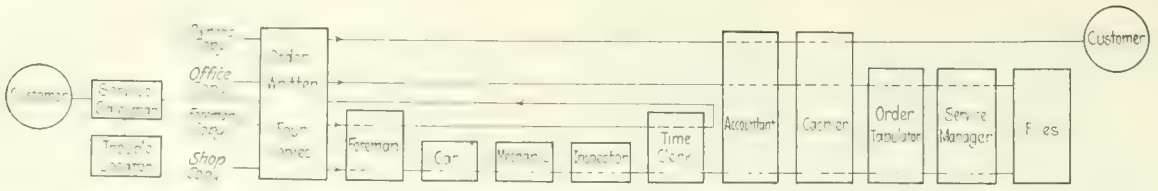


FIG. 7.—DIAGRAM ILLUSTRATING THE ROUTING OF THE FOUR COPIES OF THE REPAIR-JOB ORDER-FORM

It is inserted under the fourth copy of the top repair-job order-form, to afford a satisfactory even surface for writing. If this were not provided, it would be difficult to write toward the right-hand end of the pad, because the pad tapers in thickness, due to the smaller size of the foreman and the shop copies.

ROUTING OF SHOP ORDERS

The routing of the four copies of the repair-job order is shown in the chart, Fig. 7. When a customer comes to the shop with his car to have some work done, he is met by a service-salesman who converses with him and thus determines what work is to be performed. If it is impossible to determine exactly what is to be done, a trouble locater is called into conference; if necessary, this man rides in the car to determine the exact nature of the work required, and he reports back to the service-salesman. This permits the service-salesman to be on the floor all the time.

Upon ascertaining the exact nature of the work to be performed, the service-salesman, by referring to his manual, shown in Fig. 8, quotes the price to be charged, and makes all arrangements with the car-owner as to whether he pays or the house shall pay for the transaction. Everything being satisfactory, he then writes the order in quadruplicate. Each operation is listed and priced and marked as to whether the customer or the house shall pay. All this is determined before the car goes to the shop.

OPERATION	PRICE
1	$2.40
2	3.20
3	9.60
4	5.80
10	8.00
22	6.90
30	3.30
31	5.80
32	2.00
33	.90

12

FIG. 8.—A TYPICAL PAGE FROM THE SERVICE-SALESMAN'S MANUAL SHOWING THE PRICES CHARGED FOR CERTAIN OPERATIONS

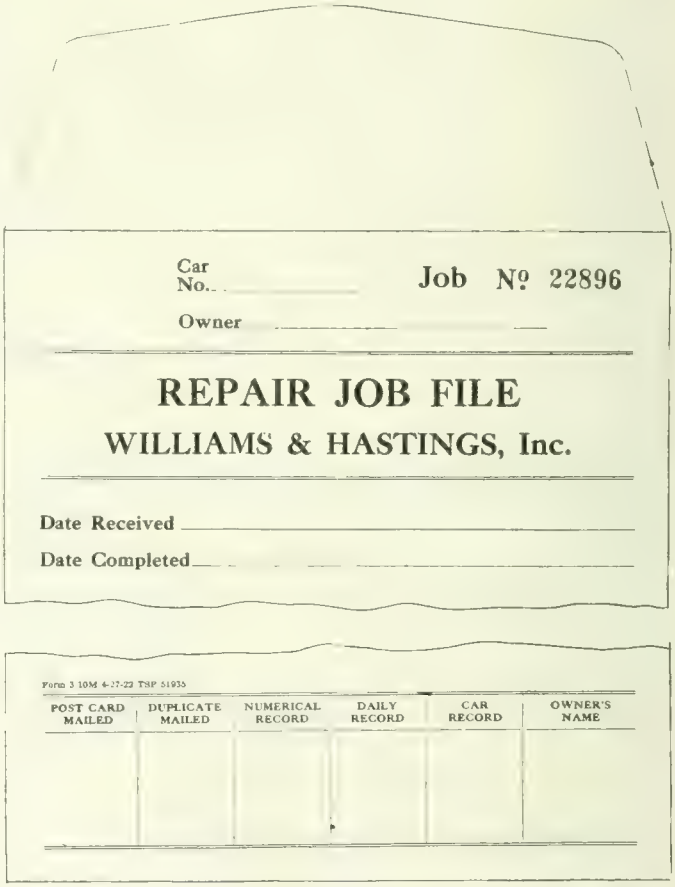


FIG. 9.—FACE OF THE ENVELOPE THAT IS USED AS A FILE WRAPPER FOR A COMPLETE REPAIR-JOB ORDER

The owner's and the office copies are sent to the accountant; and the foreman's and the shop copies, along with the car, are sent to the foreman. The foreman sends his copy direct to the time clerk, who holds it as a follow-up. The shop copy is placed in a pocket attached to the radiator of the car, and it stays with the car until the job is finished.

The mechanic then performs the work outlined on the shop, or fourth, copy, and when it is finished he calls in the inspector who passes upon the work. If it is unsatisfactory, the mechanic makes the necessary corrections before the inspector will pass it. In addition to the inspection of the mechanic's work by the inspector, the foreman is called to look the job over before the

inspector. The inspector must place his O. K. on the shop copy of the job order before the car is released. This copy then goes to the time clerk, who stamps it to indicate that all time slips and requisitions have been sent through, matches up the shop copy with the foreman's copy and sends the latter back to the service-salesman. The shop copy is then sent to the accountant's office, where it is matched-up with the owner's and the office copies that are being held. In the meantime, all charges for straight-time labor, parts, accessories or outside work, have been filled-in on the owner's and the office copies as fast as the necessary information reached the accountant. When the shop copy reaches the accountant, he makes the final entries, totalling the various items and computing the charges to the house and to the customer. As soon as the customer's invoice is completed, the owner's, the office and the shop copies all are forwarded to the cashier.

The repair order is held by the cashier until the owner arrives and pays his charges. Then the cashier receipts the first or original copy, stamping it paid, and delivers it to the customer. The shop copy and the office copy are then sent to the desk of the order tabulator, where all information is compiled, and a complete statistical chart is made that covers the transaction. The order is then sent to the service manager, who thereby has complete knowledge of the nature of the work performed, the length of time required and the like. This keeps him in direct touch with the shop on all jobs. Afterward, he sends the order to be filed for future reference as a complete record of the transaction. The face of the envelope used as a file-wrapper is shown in Fig. 9.

Repair Parts

If, during the course of the repair work, it becomes necessary to install new parts, the mechanic who does the work notifies the time clerk; the latter makes out a store's requisition in duplicate, as shown in Fig. 10, listing the names of the material desired. Both copies are sent to the parts department, as shown in the left hand of Fig. 11, where the part number and the price are inserted on both copies and the order filled by the stockroom. The parts clerk then delivers the original to the accountant, who attaches it to the customer's order and enters the prices on the customer's invoice and the office copy. The duplicate of the store's requisition is given to the stock-record keeper, who makes the necessary entry on the stock-record card. If it becomes necessary to have work done outside of the repair-shop, or to order parts that are not carried in stock, the same stores requisition is used and sent to the purchasing agent, who takes the necessary steps to see that it is taken care of immediately.

It happens occasionally that more parts are drawn from the stockroom than are required for the particular job. In this case a receiving memorandum, shown in Fig. 12, which is printed in duplicate, in red, is filled-out by the time clerk and returned with the surplus parts to the stockroom. One copy, when filled-in with the part numbers and the price, goes to the accountant; the other copy goes to the stock-record keeper. The necessary entries are made by each on the repair-job order-form and the stock-record cards. The routing of the stores requisitions and that of the time slips is shown diagramatically in Fig. 11.

Timekeeping

To keep the time records for each man properly, a special form was developed as shown in Fig. 13. This

11/15/1922 DATE	WANTED	SUPPLIES	19652 R J O No

QUANTITY	PART NUMBER	DESCRIPTION	PRICE	AMOUNT
1	AC 126	C. G. Front Bumper - Black		17 50
1.	Gal.	Cylinder Oil		1 00
1	45143	Cylinder Head Gasket		60
1	45215	Water Header Gasket		03

J. A. S. APPROVED BY	S. M. STOCK ISSUED BY	S. M. PRICED BY	X POSTED

FORM 2 10M 9 16-22 C66 P655 **STORES REQUISITION** WILLIAMS & HASTINGS, INC

Fig. 10—Requisitions for Parts Needed by the Shop Are Written in Duplicate on This Form

form is printed in quadruplicate, on one sheet of paper; two copies of the form appear on each side of the sheet, and they are spaced in such a way that, when folded, the four copies register with each other. Three sheets of carbon paper are used; so, all the records of time required are made at the one writing. The first and second copies are perforated so that the individual slip, giving the time for each operation, can be detached.

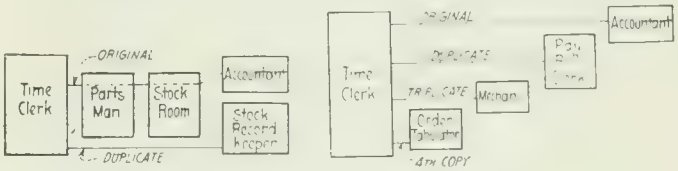


Fig. 11—The Routing of the Stores Requisition, Reproduced in Fig. 10, Is Shown at the Left and That of the Time Slips, Reproduced in Fig. 13, Is Outlined at the Right

In practice, the time slips are made out in pencil by the time clerk. The time is stamped on the clock by the time clerk, who is notified by the mechanic whenever he starts or completes an operation.

When a man starts on an operation, he reports the repair-job order-number and the operation number to the time clerk, who makes the necessary entries on the slip. When the man completes this operation he again reports to the time clerk, who stamps the previous operation completed and rings the man in on the next opera-

WILLIAMS & HASTINGS, INC
DETROIT, MICH

RECEIVING MEMO NO 7167

RECEIVED FROM

PURCH ORDER NO

DATE

QUANTITY NUMBER ARTICLE PRICE EXTENSION TOTAL

RECEIVED BY CHARGE ACCT APPROVED BY

RECEIVING MEMO.

Fig. 12—Where More Parts Are Drawn from the Stockroom than Are Needed, the Surplus Accompanied by a Receiving Memorandum Are Returned

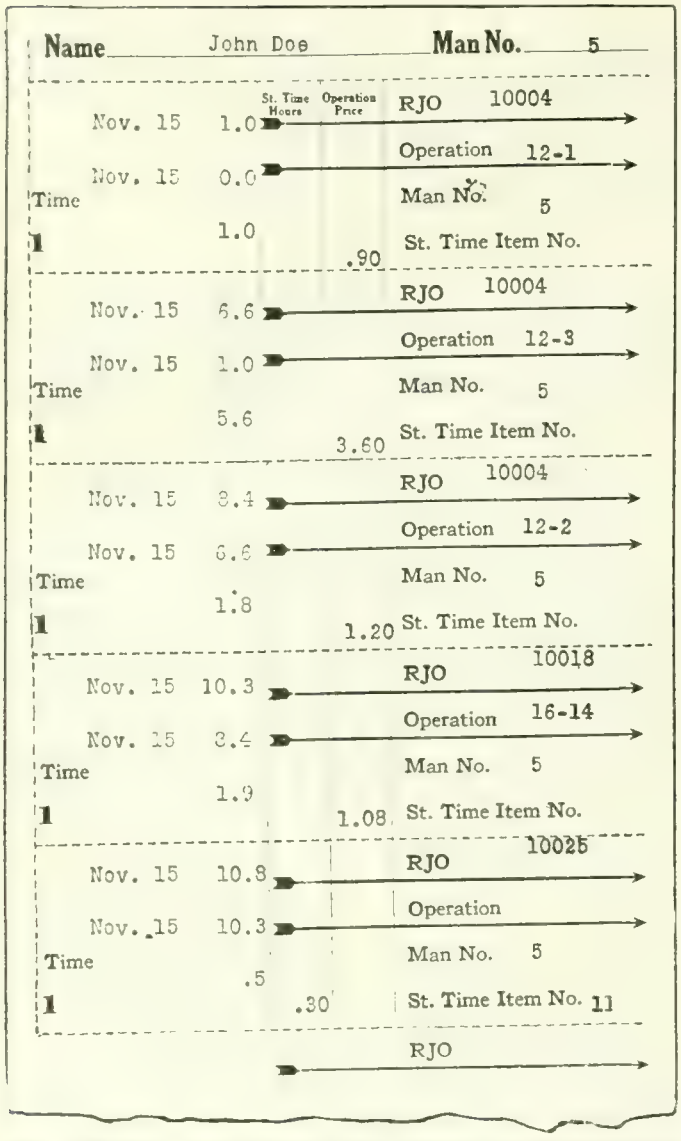


FIG. 13—SPECIAL TIME-RECORD SLIPS, PRINTED IN QUADRUPLICATE, ARE USED TO KEEP TRACK OF THE TIME SPENT ON A PARTICULAR OPERATION

tion. The time clerk then computes the elapsed time for the completed operation and notes it on the time slip.

In the case of a contract-labor operation, he inserts the amount to be paid the man in the column headed "operation price." If the particular operation is one based on straight time, he multiplies the elapsed time by the workman's straight-time rate and inserts the figure under the heading, "straight-time hours." As each operation is completed, the perforated copies are detached; one is sent to the accountant, who enters the charge on the repair-job order, and the other is sent to the shop foreman or service manager, who can thus follow the progress of the work. It also enables the foreman or service manager to check quickly any time taken on a flat-rate operation that varies greatly from the established average. In case of such extreme variation, an immediate investigation is instituted to ascertain whether the work has been done properly or why the man has required so much time on that particular job. The third copy of the time slip is sent to the payroll-clerk at the end of each day, who tabulates the amount due each man. The fourth copy is given the individual mechanic, so that he can check-up the amount due him in case there is anything wrong.

In the event of some condition arising over which the mechanic has no control, whereby a job cannot be performed in the allotted time, it is the duty of the foreman or service manager to make a thorough investigation; and, if he deems it advisable, the mechanic can be transferred to straight time for the particular job. For example, if an owner's car is brought in to have the valves ground, and if the mechanic should strip one of the studs when tightening down the cylinder-head in assembling, while using the proper tools, he should not be held responsible; in this event, his day-rate time should be allowed him in making the necessary repairs. On the other hand, if the car came into the shop for valve-grinding and it was found that it was necessary to install new valves and make repairs to the cylinder valve-seats other than ordinary reaming, it would then be necessary to ask the owner for his permission to make an additional order covering this operation. When a mechanic is working on straight time, he is paid his regular hourly-rate as recorded on the payroll. Not all the mechanics in the shop receive the same hourly-rate but, when doing contract work, they all receive the same amount of money for the same job.

All operations on which a contract has been made and a price allowed for doing the work are posted in the shop; so, when a mechanic is assigned to a particular job he can tell instantly exactly how much money he will receive for the work by referring to the bulletin-board. On the same bulletin-board are also listed, in red, the jobs on which a minimum time has been established, and the mechanic must not perform the work in less time than this, because experience has proved that to do so only means the slighting of the work and the possibility of having to do it again. There are but few of these jobs, however; they consist of those cases in which inspection after the job is done is difficult or impossible.

At this point it is well to note that, with the exception of the minimum time mentioned, the workman views the various operations strictly from a dollars-and-cents point of view. He knows from the lists how much money he is to be paid for each operation and proceeds to earn that money with as little delay as possible. The actual time allowed for each operation is not listed in the shop, nor is it discussed with the men. The master list is filed in the service-manager's office.

The service-salesman must be thoroughly familiar with the mechanical structure of the car, and also with the work apt to be required on it. He must also familiarize himself with the operations that have been listed and written out in detail. For this reason he is furnished with a complete set of the operation sheets arranged in order, in loose-leaf binders. For ordinary use, while he is writing-up orders, he is provided also with a loose-leaf binder containing only a complete set of the index sheets to the operation sheets. He has in addition a small loose-leaf notebook which contains a complete list of the operation numbers and the customer's price for each. A typical sheet from the notebook is shown in Fig. 8.

PRICE REVISION

The time required for all contract operations is recorded each day on summary sheets, a sample of which is shown in Fig. 14. About once a month the average time for each operation is checked-up. If the time has changed materially from that on which the contract rate is based, the service manager and the statistician discuss the situation with me and a decision is made regarding changes

in the contract price to the customer and also in the piece-work rate to the mechanic. If it is found that work can be performed in much less time than that on which the contract rate is based, it is to the advantage of the house to reduce prices, although we bear in mind that it is unwise to cut the mechanic's time so low that he cannot earn more money doing contract work than he can at his established day-rate. He must have the incentive to do good work in the proper time, and this can only consist of increased earnings.

Our experience has shown that the men's average earnings have increased from about 65 cents per hr. under the old straight-time methods to about 81 cents per hr. on the piece-work plan. At the same time, the output per man has been increased about 40 per cent. When rate revision was last considered, it was found that there were five operations on which the rates should be lowered, and the same number on which the rates needed to be increased. These changes met with no opposition from the men in the shop, as they appreciate that these revisions are all fair to them. This is indicated by the above statement in regard to the last rate-changes.

Control Chart

To obtain the best results from the flat-rate and piece-work system, we found it desirable to employ a control sheet so as to picture clearly, for the service manager, the results being obtained. Among other items which are tabulated daily are the

(1) Number of repair-jobs completed
(2) Number of operations performed
(3) Number of repair orders performed in each hourly time-group
(4) Average number of hours per repair-order
(5) Total amount collected for repair work
(6) Average amount collected per repair-order
(7) Total house-charges on repair-orders
(8) Number of hours on contract work
(9) Number of straight-time hours
(10) Ratio of straight time to contract time
(11) Ratio of productive to non-productive labor
(12) Time spent on guarantee or policy work

It is not absolutely necessary that this control chart be used, but some of the small points that require correction are apt to be passed unnoticed if some such chart is not used. For instance, any repair-order put into the shop on which less than 2 hr. of work is specified is a losing proposition, due to the amount of overhead that must be charged against each repair-order. It is unavoidable that some small orders go into the shop, but the service-salesman should be coached to endeavor to sell additional work to those owners who come in only

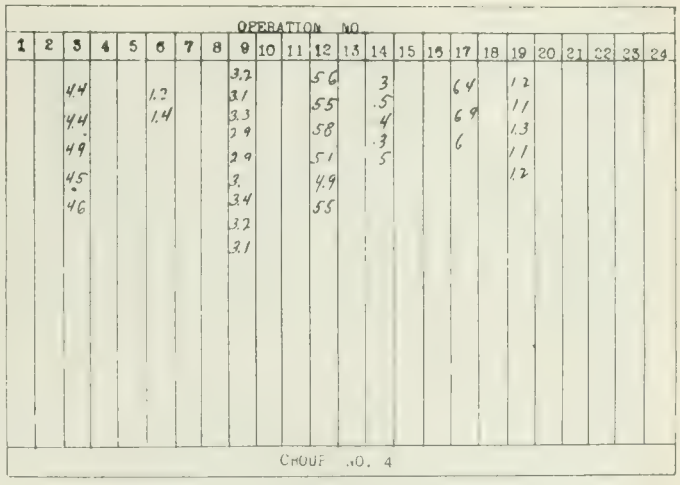


Fig. 14—Summary Sheet on Which the Time Required for All Contract Operations Is Recorded

for one or two small jobs. If the number of short-time jobs could be decreased greatly it would be possible to reduce contract-rate charges materially on the jobs that run to more than 2 hr. of time.

Limitations of the Flat-Rate and Piece-Work System

The combined flat-rate and piece-work system can be used satisfactorily only in those shops that are large enough to warrant the installation of a timekeeper and a suitable accurate time-clock. If the number of men employed or the varying volume of repair work does not warrant the employment of a timekeeper, it is useless to attempt to put in piece-work. Regardless of the size of the shop, the flat-rate system of charges to the owner should be adopted. At the present time, owners will never be satisfied until they know in advance what the labor on their car is going to cost them. A service manager who makes a note of the owners' requirements on the back of an old envelope is probably a good scout, and he intends to be perfectly fair, but his assurance to the owner that "the charges will be all right" is far from satisfactory to the owner. To illustrate how the same repair-order can be used to advantage in a small shop, the chart shown in Fig. 15 has been prepared. This shows the number of non-productive men very considerably reduced, although the same procedure is followed as in the large shop.

Guarantee or Policy Work

The new car-guarantee used by the builder of the car I represent is the same as that used by practically all other motor-car companies. In a brief general way we interpret this to mean that we will make right for the

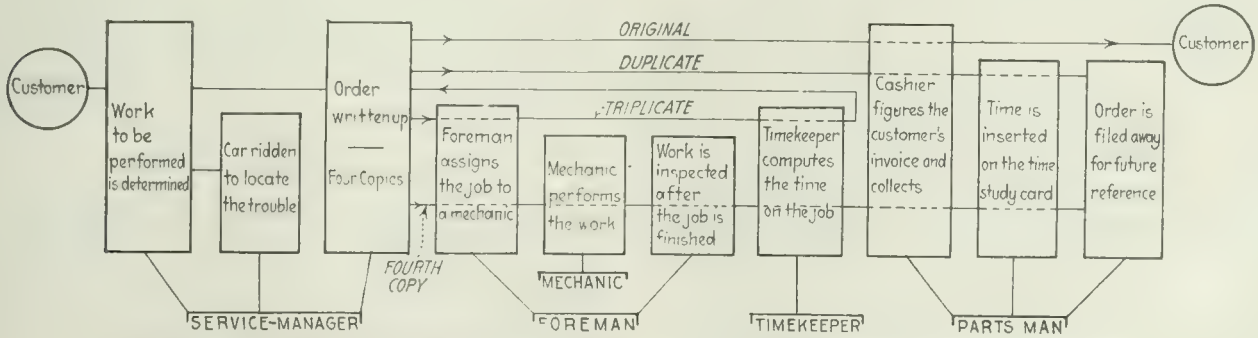


Fig. 15—Chart Illustrating the Application of the Repair-Job Order-System to a Small Shop

owner anything that is defective about the car for which the factory or our company is responsible. This guarantee applies for a period of 90 days to the original purchaser of any new car sold at retail by our company.

To enable the service-salesman to pass intelligently on claims for policy work, he is provided with a list of purchasers of new cars. This list is kept in the form of a visible tube-index, each line giving one car-number, the owner's name and the date of purchase. This is kept uptodate; the names of owners whose cars are more than 4 months old are removed periodically. Policy work without charge to the owner is not confined strictly to the 90-day period, as cases sometimes arise where the owner is clearly entitled to relief even though the car is considerably beyond the 90-day period. Such cases are usually passed on by the service-salesman if no great expense is involved. Where the justice of the owner's claim is debatable, the service manager is asked to handle the matter.

Parts Department

The equipping and handling of the parts department has required intensive study along the several lines of

(1) Storage of parts
(2) Parts records
(3) Purchasing
(4) Shipments
(5) Deliveries

The fundamental rule adopted in regard to the storage of parts is to have a specific location for each different part and, under no conditions, to have more than one kind of part in a given location. The equipment used to secure this result consists of stock-bins of various sizes, steel cabinets each containing 60 steel drawers, racks for such articles as fenders, bumpers and springs, and shelves for certain miscellaneous articles. The stock-bins are made in sections and constructed of wood with ¼-in.-mesh wire-screen for the back. The sections are from 5 to 6 ft. long and about 3 ft. high; the depth varies from 12 to 16 in. These sectional bins are arranged in groups of 12; 4 of the 16-in. sections form the base, there are two layers of four 12-in. sections each on top of this base, the upper layer consisting of bins 6-in. wide for smaller parts. Each section of these bins is given an identifying letter, and a standard numbering-system for locating the bins in each section has been adopted. Each bin carries on its face a card showing the part-number of the piece in that particular bin. Wooden bins were adopted because, 3 years ago, the modern steel bins were still in the development stage. If new equipment were being purchased at present, it is probable that the steel bin would be the better, although, in case it is necessary to shift the locations of bins, the sectional wooden construction has a decided advantage.

The steel cabinets, each carrying 60 drawers, are ideal for the storage of small parts. Each drawer can be subdivided into from two to eight sections; so, a great quantity of parts can be carried in a relatively small space. At present, we have seven of these steel cabinets; they have an average of four divisions to each drawer and can store a total number of parts approximating 1700 in a floor-space of about 21 sq. ft. This group of steel cabinets has an identifying symbol and the drawers are numbered consecutively in each row. The top row starts with the number 100; the second row, with 200; and so on to 1500 for the bottom row. The part-number applying to the material in each section of each drawer is printed on a white card which is glued to the partition or the back of the drawer as required.

The gasket boards on which gaskets, switch keys, shims and similar small parts are mounted, are made of 1¼-in. tongue-and-groove lumber, faced with beaverboard, which is painted black. Cornice hooks, ranging in length from 2 to 7 in., depending upon the size and number of the articles to be supported, are screwed into this board. The racks were designed in each instance to suit the particular material to be stored. The racks for springs, bumpers, axle shafts and similar parts, each consist of two 4 x 4-in. timbers, set on-end and bolted solidly to the wall. Pieces of ½-in. steel-rod are imbedded in pairs, in these 4 x 4-in. timbers at intervals of from 4 to 10 in., the length of the pins projecting from the timbers varying from 6 to 12 in.

The fender racks consist of a frame work of 2 x 4-in. lumber supporting narrow wooden shelves on which the ends of the fenders can rest. The fenders are carried in the same position as that in which they are mounted on the car, each adjacent pair of racks carrying corresponding right and left fenders, the left-hand rack in each case carrying the left-hand fender. This permits the fenders to be nested one above the other with very little waste space, and practically eliminates any scratching of the enamel.

Special racks for carrying valves, piston-rings and similar parts, have been made as required. The piston-ring rack, for instance, consists of a heavy wooden support, on which are mounted cylindrical wooden blocks of such a size that the piston-rings just slip over them. Provision is made at one side of this rack for carrying the standard and over-size inspection gages. Every piston-ring is checked with these gages before it is sold or delivered to the shop, to eliminate any chance of the wrong size of ring being delivered.

The location of the bins, cabinets and the like has been studied with a view to saving steps for the men in the parts department as much as possible. Those parts for which there is the greatest call are located within a few feet of the sales-counter. This study has resulted in eliminating the services of one stock-clerk entirely.

Parts Records

A parts department of any size involves the keeping of stock records which show stock on order, stock on hand, sales and the like. In other words, the records form a perpetual-inventory system.

We struggled with the ordinary vertical card-file, thoroughly indexed, for 2 years. We found that cards were occasionally misfiled, resulting in great delay and confusion; also, that the cards themselves became crushed and dirty along the upper edge. To overcome these conditions, we installed a loose-leaf stock-record system about a year ago, each sheet being approximately 12 in. wide and 6 in. high. These sheets are carried in special ring-binders which are about 13 in. wide and 16 in. long. The sheets are arranged in these binders in groups of 15 to 20, in such a manner that the lower ½ in. of each sheet is exposed. On this lower section of each sheet appear the part name and the part number. In front of each group of sheets there is an index sheet with a tab on the right-hand side, which carries the part number of the upper sheet in the group. These binders are each about 4 in. thick and, as they are rather heavy, are handled in a special desk provided with rollers so that they can be moved toward or away from the clerk with practically no effort. This system enables the record sheet for any given part to be located almost instantly, and entirely eliminates the chance of a sheet being lost or misfiled,

as the sheets remain permanently in place in the binders while all posting is being done.

To facilitate the locating of parts when the part-numbers are known, a tubular visible-index system has been installed. This consists of a rotary stand on which are mounted about a dozen, two-column, double-faced, panels, carrying about 90 celluloid tubes to each column. In each tube is inserted a typewritten slip carrying a part-number and its corresponding location. These part-numbers are, of course, arranged in numerical order. Indexing is accomplished by using celluloid tubes of twice the usual width, in which green or other colored slips with large figures are inserted. This index is readily kept uptodate, easily accessible and avoids the constant handling of stock-record cards required when the cards must be consulted to determine locations.

Purchasing

The purchasing of parts from the factory is based generally on the maintenance of stock, between certain minimum and maximum limits. We intend to have on hand any part for which there has been a single call in the last 6 months and, at the same time, we do not wish to have more money invested in the parts than is necessary. In accomplishing the above results, the minimum has been established at 1 month's supply, this figure being the average of the disbursements for the preceding 3 months. The maximum is established at 1½ times the minimum. Working to these figures involves the checking of the minimum for each part at the first of each month. It also involves the checking of the stock on hand against the minimum and the maximum, by the stock-record clerk, each time an entry is made in the stock-record. If the quantity on hand is too high or too low on any part, a report is made to the manager of the parts department, who sees that the necessary purchase-order is written and the stock secured.

A departure is made from the minimum or maximum mentioned when it is advisable in the judgment of the parts-department manager. For example, certain parts are sold by the factory in standard packages of 25 or 50. It is much better to buy the standard package, even though the quantity runs over the maximum, as it simplifies the handling at the factory and does not result in a greatly increased investment. Again, there is a seasonable variation in the call for certain parts, such as skid-chains. The big demand for these occurs in November and December and, if we work to the minimum established on the basis of August, September and October sales, the stock would be entirely inadequate. On the other hand, if the stock of skid-chains in February were based on sales in November, December and January, it would result in the carrying of a large inventory through the summer which is, of course, entirely unwarranted. Another factor influencing the purchase of accessories is the variation in discount with the size of the order. Careful attention and extremely good judgment are required in purchasing such material, if excess stock and possible loss, due to price changes, are to be avoided.

Shipments and Deliveries

Shipments of parts to dealers or other out-of-town purchasers are made ordinarily the same day on which the order is received, or at least on the following day. Special attention is given to telegraphic orders immediately upon their receipt. Large articles, such as fenders and radiators, are carried crated, ready for shipment, thus avoiding the delay incident to crating and packing.

The parts department is located on the first floor, and the shop is on the floor immediately overhead. A basket parcel-carrier, such as is used in shoe stores, was installed. By means of this requisitions, time-slips and the like are sent from the shop to the parts department, and any parts weighing not over 10 lb. and of reasonable size are delivered automatically to the shop without requiring a mechanic to leave his work and without requiring a messenger. Retail purchasers of parts are served over a long counter; at one end of this the cashier's desk is located. The parts-department organization has been

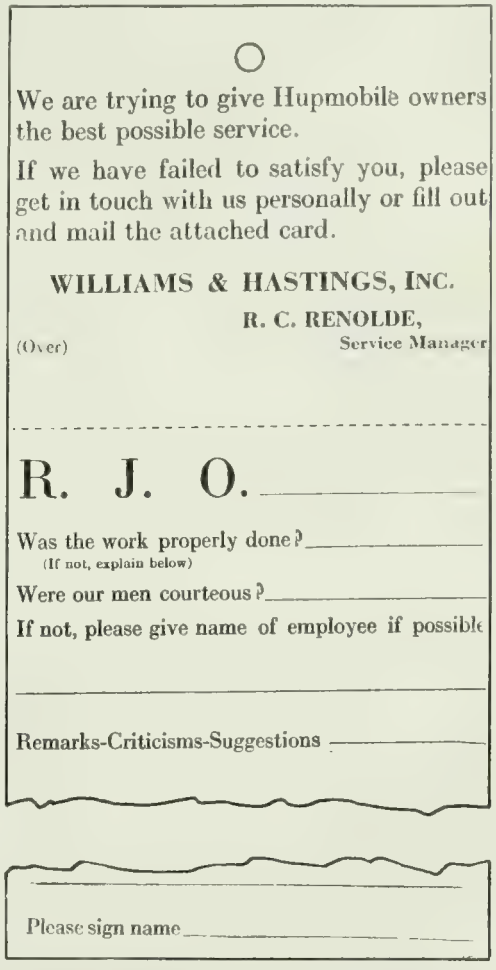

We are trying to give Hupmobile owners the best possible service.
If we have failed to satisfy you, please get in touch with us personally or fill out and mail the attached card.
WILLIAMS & HASTINGS, INC.
R. C. RENOLDE,
Service Manager
(Over)
R. J. O.
Was the work properly done?
(If not, explain below)
Were our men courteous?
If not, please give name of employee if possible
Remarks-Criticisms-Suggestions
Please sign name

Fig. 16—This Tag Attached to the Steering-Wheel of Each Car That Leaves the Shop Provides a Means for Following-Up Repair Work

taught that promptness, courtesy and cleanliness are just as essential in the parts department as they are in the shop or service-department proper. The result is that the personnel is up on its toes, striving to satisfy the customers at all times.

Follow-Up on Repair-Jobs

Various methods have been tried for following-up repair-work, to make sure that the owner is satisfied. The reply postal-card, mailed a day or two after the owner has taken his car, was tried for several months but did not prove very satisfactory. We next attempted to have the service-salesman telephone each car-owner a day or two after he had driven away. This proved impracticable, as frequently three or four telephone calls would fail to reach the owner. It was likewise expensive, in both telephone bills and the time required of the

service-salesmen. At present, the form shown in Fig. 16 is used. This is printed on fairly heavy tag-stock, and has a wire for attaching it to the steering-wheel. The repair order-number is filled-in by the inspector when he approves the work; and the tag is attached to the car. The tag is perforated so that the larger portion, when detached, constitutes a postal-card. Each one of these carries a 1-cent stamp; so, all the owner has to do is to fill-in and sign the card and drop it into a mail-box.

In the effort to give the personal touch to this follow-up, the cards are addressed to our service manager, and all of them are scrutinized by him when received. If the owner reports anything unsatisfactory, an immediate investigation is made. The owner is asked to bring his car in again as soon as possible if the dissatisfaction concerns some mechanical feature. The fact that the card is called prominently to his attention when he takes his car away impresses him with our earnestness in trying to give the best possible service, and results in getting a greater percentage of replies than other methods.

Cleanliness

The one thing that can build-up in an owner's mind, more quickly than anything else, a prejudice against a service-station, is to have his car delivered to him in a dirty or greasy condition. Imagine a lady who wears white gloves driving her car away from a service-station and finding, after a block or two, that her gloves are covered with grease. Or, suppose this same lady has on a white summer dress and, on getting out of her car, finds that the back of it is anything but presentable. No matter how good the mechanical work may have been or how courteous the men, you immediately have a dissatisfied customer.

We have taken extreme measures in endeavoring to deliver cars that are satisfactory in this respect. Mechanics are required to wear clean overalls. To assist in enforcing this regulation, our company stands the expense of washing all mechanics' overalls or shop coats. We also buy these garments in fairly large quantities and sell them to the men at cost. To protect the more or less delicate upholstery in closed cars, the men are required to cover the seats with clean cloths before entering a closed car. After a car is marked O.K. for delivery to the customer, it is inspected both inside and out, and any necessary cleaning is done. Particular attention is paid to the upholstery, the steering-wheel and the handles of all control levers. This work requires the services of at least one additional man, and at times two men, depending upon the volume of work going through the shop. We believe this expense is well justified; in fact, that this service must be rendered if satisfactory relations with customers are to be maintained.

General Results

After having used the flat-rate system for something over 1 year and the piece-work system for about 6 months, we are thoroughly sold on both. If we were to organize a new service-station today, we would immediately concentrate on obtaining the necessary data to install both of these systems. In fact, we would guess as closely as possible at the probable time-requirement of each operation and figure the corresponding charges to customers and the piece-work rates to the men, putting this system into operation at once and making any necessary adjustments as rapidly as possible in the light of experience.

As mentioned, the production per man has been increased about 40 per cent and the men's earnings have increased about 25 per cent. This 40-per cent increase in production covers the total production in the shop, regardless of whether it is on a piece-work or a straight-time basis. Of the total shop-time recently, between 50 and 60 per cent has been on the piece-work basis. We estimate that if we reach a basis of 75 per cent piece-work and 25 per cent straight-time, we will have attained the maximum.

If the operations now done on piece-work are considered alone, the production per man has increased very much more than 40 per cent. As an example of the decrease in the time on a given operation, we might mention the installation of bumpers. When this was done on straight time, the average cost to us in direct wages to the man was about $0.85. The piece-work rate for this same bumper-installation at present is $0.30. This is only slightly over one-third of the former charge, and yet the men are making more money per day.

We have always taken the attitude that we have no secrets in our business. Anything that we can tell to a competitor that will be of assistance to him in raising the plane on which his business is conducted will, in the long run, be of assistance to us through helping to change the mental picture carried by the average car-owner. Our service organization has spent many days in explaining to representatives of other factories and other dealers how and why we do various things. We expect to continue this policy and are always glad to have anyone seriously interested in these problems call on us and spend as much time with us as he wishes. We have had many requests for information by mail, but have discouraged this as much as possible. It is very difficult to give a picture in writing of any one phase of the service problem, as they are all so intimately related.

Automotive-Service Cooperation Between Manufacturer and Dealer

By J. F. Page[1]

Chicago Service Meeting Paper

STATING that the kind of service cooperation needed between the manufacturer and the men in the field is the type that assists and encourages as well as supervises and dictates, the author comments briefly on varied phases of the subject. Among these are the importance of familiarity with conditions in the field, the type of factory field-representative desirable and the necessity of keeping him posted on all changes in design and adjustment.

Stock-department supervision is an important factor, as a check against over-stocking by dealers, and the advantages of standardization and interchangeability of parts are re-stated. Great emphasis is placed upon the desirability of rigid final car-inspections and accurate adjustments at the factory, before the cars are delivered to the dealers. The holding of periodic service-meetings is mentioned as an essential part of the duties of the factory service-department.

I DO not agree with those service-men who, in effect, would say to a manufacturer: Leave us alone, we have troubles enough. The manufacturer can be of real assistance to the dealer in regard to service problems; he certainly should be interested just as much in seeing that the proper service is being given as he is in the sales problem, since one is inseparably tied-up with the other. The kind of service cooperation needed between the factory and the men in the field is the kind that assists and encourages as well as supervises and dictates. Too often the best results are prevented and progress blocked by a factory policy of stern dictation or, worse still, the having of no definite service policy or standards. A definite policy should be established by the manufacturer, that is understood and lived up to by the dealer.

There are service problems peculiar to the size of the dealer's organization and territory just as there are sales problems. Again, there are problems common to all and only an open-minded and intelligent factory service-department can give the constructive cooperation needed to accomplish definite and satisfactory results. The factory service-organization should be striving constantly for better service to the car-owner, and there are definite ways in which the service-men in the field can be assisted and service to the customer improved.

Field Conditions

To accomplish anything worthwhile the factory must be familiar with the conditions in the field. Such knowledge can be obtained only at first hand; that is, by personal contact with the service-man and an appreciation of his problems. This means that factory representatives must travel over the territory. The first essential to their success is that these men have the right personality to size-up those with whom they come in contact and know how to deal with them. This is work that requires patience, tact, a thorough knowledge not only of the mechanical features of the particular car but of service problems in general, proper methods of stock-keeping, layout, organization and the like, together with the ability to apply such knowledge to conditions as they find them. Where service is carried on through large branches, the work of supervision and assistance may be divided among specialists, but the representative who covers a large territory comprising many dealers needs to be a very versatile individual to get the maximum in results and accomplish a real improvement in service. Such men should have a training made up of both field and factory experience.

Suggestions sent to the factory should be acknowledged promptly and considered carefully. The engineering department especially should be liberal in the attention given to such suggestions as properly may be made to that department. Nothing stifles initiative and constructive suggestions so surely as a policy of disinterestedness or actual antagonism on the part of the manufacturer. Out of many suggestions offered, only one may be worthy of adoption; but that one may be so good as to make worthwhile the time and trouble of treating all the others in such a way as to encourage the interest and the loyalty of the men in the field. Further, the manufacturing and the engineering departments should be careful to keep the men in the field accurately posted on all changes in design or adjustment, and some system is necessary for sending out such information in letters or bulletins. The dealer, in turn, must see to it that this information reaches all those in his organization who should receive it.

The dealer and the manufacturer will benefit from a spirit of open-mindedness and mutual assistance, yet such a spirit is far from universal today between factory and dealer organizations. With out the proper spirit of cooperation, neither the manufacturer nor the dealer will make the most of the opportunities at hand. The manufacturer should maintain a cost department containing accurate data on parts costs, and the prices of parts should be stabilized and listed in parts-books clearly and intelligently arranged. Much time and money can be saved or lost, depending on whether these lists are constructed properly.

Stock-Department Supervision

Supervision of stock departments is very important. Improper stock-keeping methods and inefficient stockmen are a prevalent source of loss and a great handicap in rendering good service. The stockroom should have close attention from both the manufacturer and the dealer. It is of no lasting advantage to the manufacturer to have a dealer who loads up with unnecessary parts, and certainly the man whose money is in the business does not want to carry a heavy, slow-moving stock; yet, I repeat, this department of the business is woefully neglected, and is a source of much loss. There certainly is no use in expecting an efficient and profitable parts-department so long as the management and responsibility are delegated to an inefficient man or boy at low wages.

The factory stock-department also can assist the dealer

[1] General manager of service Packard Motor Car Co. of Chicago, Chicago.

greatly by arranging to dispose of obsolete parts that have accumulated through no fault of the stock-keeper. The factory should be able to inform the dealer's stockman in regard to the necessary parts and amount of stock to carry, with reference to the number of cars of given model in the dealer's service territory. Thus, again, the top-heavy inventory will be avoided and, at the same time, the necessary variety of parts for proper service will be in the stock-bins.

Standardization and interchangeability of parts are of such obvious advantage in giving good service and in making possible a smaller parts-stock as scarcely to need any urging upon the manufacturer, yet many an exasperated service-man will say that his life would be easier and the service better if much greater care and attention were given these problems by the engineering and the manufacturing departments.

Through collaboration with the service-stations, definite standards of work and job specifications, together with time-studies, can be worked-out at the factory for practically all shop operations. This work naturally will include an investigation of shop methods, the designing of special time-saving tools and the like. The results of all this will be the standardizing of service to the car-owners, an increase in shop efficiency and a corresponding lowering of costs; and it will make possible the establishment of flat prices for service work. Nothing is more clearly needed in the automotive industry than a universal custom of quoting definite prices for repairs. It is possible to accomplish this, and it must become a fixed policy in the service methods of every successful distributor.

Factory Car-Inspections

Too much emphasis cannot be given to the matter of final inspections and adjustments at the factory before cars are delivered into the dealers' hands. The new owner's first impressions are often the lasting ones, in regard to the car and to the company back of it. It should not be necessary or expected of the dealer that he spend a big slice of his profit in getting cars ready to deliver in only such standard condition as the manufacturer himself would want to have his cars delivered to owners.

A very necessary part of the duties of the factory service-department is the periodic holding of service meetings. These should be conducted carefully and follow a definite program of an instructive and constructive nature, giving plenty of opportunity for the free exchange of ideas on every problem. There are plenty of problems with which the many-sided service-man is faced.

It is not to be inferred from these remarks that the manufacturer is expected to assume entire responsibility for the quality of service rendered by his dealers, nor is it even faintly suggested that the service-man is without shortcomings in many cases. There is much room for improvement in service everywhere, and not nearly enough attention is given this phase of the sales problem. Any distributor who expects lasting success has a perverted sense of values if, after selling the customer in a beautiful and often luxurious salesroom, he condemns him and the car to an inadequate, poorly organized service-system for all the rest of his associations with the company.

Fortunately, there are encouraging signs of a proper appreciation of service values; as shown by the increasing number of splendid plants being constructed solely for service purposes in the larger centers of distribution. The responsibility for good service is a mutual one of the manufacturer and the dealer and, for their lasting success, it means the closest kind of cooperation in all that pertains to improving service and increasing sales. For, after all, the two problems are one.

RESERVE RESOURCES

THE strength of every business situation is in reserve resources. If everybody was careful to have ample resources in reserve there would be no crises. Our Federal Reserve System was planned to have ample reserve resources, but all banks came out of the war period very much extended. They did not have the resources in reserve that they were planned to have, and that with a proper regard for security they should have. The Joint Commission of Agricultural Inquiry expresses the opinion that steps should have been taken to check inflation earlier than was done, and this opinion I am bound to say is well supported in the judgment of the banking community.

If I wanted to state in the fewest possible words an explanation of the agricultural distress of the last two years, I should put it in three words, Too much borrowing. The wholesome fear of debt that was prevalent when some of us were young has been largely dissipated by the rising prices of the last 25 years. Men have been led to believe that the way to get ahead is by the use of borrowed money, and that the smaller the margins on which they operate the more rapid their progress will be. The truth is that the number of men able to use borrowed money advantageously always has been comparatively small.

I do not wish to be understood as representing farmers as a class as more imprudent or reckless than other people, including business men generally. They had plenty of good company, both in borrowing and in losing. They did just what most business men did; and the combined effect of this general policy of inflation was to overdo the use of credit, create an abnormal price-level and bring about a disastrous reaction. It is pertinent, however, to point out at this time, when relief for the farmer is proposed through various plans for providing him with more credit, that the chief factor in the plight in which he is now struggling has been too much credit. I do not know of any branch of agriculture in which at this time production is deficient for the want of credit. I think there is more agitation for means of restricting production than for means of increasing it. It is probable that the class of farmers who are in deepest distress now would be in still deeper distress if prices went lower as a result of placing increased facilities for production at the command of the more efficient class of farmers. It has been stated in a leading farm journal that

> In spite of the temporarily bad situation, so far as the average Iowa farmer is concerned, there are thousands of farmers, who own their own farms and who saved their money during the war, who are better off than they have ever been.

The class of farmer referred to belongs to the class of men in every line of business, who are the leaders and price-makers, and make conditions difficult for competitors.—George E. Roberts before Academy of Political Science.

The Connection of the Research Committee with Fuel Research[1]

By H. M. Crane[2]

I SPEAK about the connection of the Research Committee with fuel research in particular because, while there have been other activities of the Research Committee, we recognize that its work for 1922 will have to stand or fall on its fuel activities. The Research Committee was a natural successor to the former Fuel Committee which I first became associated with about 3 years ago. At that time the position of the automotive industry in regard to fuel was very much the same as that of the turkey about 3 days before Thanksgiving; it thought the axe was going to fall, but it did not know just when or where it would hit, in regard to the kind of fuel it would be asked to use.

It was plain that we did not know nearly enough about the fuel problem, about how fuel was made or how it could be or should be made; or, from our own side of the question, how it could best be used. It seemed to me then and to the other members of the Fuel Committee that the obvious thing to do was to get nearer to the technical men in the oil industry, for one thing, and also that all of the technical men in our own industry should draw more closely together on the particular question of design, which looked at that time as if it might be the limiting factor in the possible use of automobiles. There seemed to be an opinion then that possibly it would be a question of how much fuel we could get, rather than of how many people we could get to buy cars. Beginning at that time, we made a consistent effort to come closer to the technical people in the oil industry and at the same time, I thought that it would be a good thing to proclaim a little more loudly some of our own difficulties, with the idea that this could not fail to help in improving the general situation.

I will pass over the intervening 2 years and come to a point about 1 year ago. We had made a very surprising advance, I think, at that time. We had our own Research Committee, while the petroleum industry had organized, in the American Petroleum Institute, a technical division under the leadership of Dr. Van H. Manning. We were in such close harmony that it became possible to proceed with a joint research on the fuel question. There is nothing like a joint research of this kind to clarify the ideas of both parties to the research. The actual working together in attempting to arrive at a just conclusion on any problem goes a long way toward making the problem itself clearer, and toward making it more certain that a just conclusion will be obtained.

Financial Support and Program

Less than a year ago we were able to get substantial support from the National Automobile Chamber of Commerce in a financial way, and from the American Petroleum Institute, for a joint research on the fuel problem. There was practically no hesitation in the minds of either your Committee or that of the American Petroleum Institute in putting the expenditure of the first of this money into the hands of the Bureau of Standards, since the Bureau of Standards had, through W. S. James, presented a program covering a method of investigating the use of automobile fuel in a number of different cars, which appeared to all of us to offer possibilities of some very substantial and useful information.

The first test under this joint proceeding was carried out in the summer of 1922 by the Bureau of Standards, and a report of the results is already in your hands. At the same time a number of companies in the Detroit district and in other places offered their cooperation in making service tests on fuel similar to those being tested at the Bureau of Standards. The paper presented by V. H. Gottschalk[3] is a result of those tests. As can be seen, these tests covered a wide range of cars under a very considerable range of operating conditions, it being understood, however, that practically all of them were carried out in summer weather.

It has seemed to me that there are two phases to this problem. One of these is in relation to the kind of fuel we would like to get, if we can. I have believed from the start that we would never get the best solution of the problem from an economical point of view, until we came to a realization of the best fuel for the purpose. From an economical point of view, however, I have recognized, and all of us have recognized, that it probably is impossible to get anything approaching what we now consider to be the absolutely best fuel. We believe that possibly from 3 to 5 times the quantity of the very best fuel is available in the form of a fuel which differs from the very best in such a small amount as to be possibly unrecognizable in the hands of many drivers. Therefore, the second phase of the problem involves what is the biggest departure from the theoretically best fuel that can be handled successfully in the present-day automobile.

The Bureau of Standards tests were directed along those lines by taking samples of cars representing something like 75 per cent of the total number of cars in use in this Country, and operating them under supposedly service conditions. The chief difference between the Bureau of Standards' tests and those carried out by the companies lies, I think, in the fact that the companies' tests represented a somewhat more advanced product than was represented in the Bureau tests; that is, many of the cars used by the companies were cars of uptodate design. The result of these tests, as a whole, from an economical point of view, was certainly satisfactory. It indicated that in warm weather, in any event, purely from a mileage point of view, a fuel considerably worse than what is now being supplied will produce mileage almost in proportion to the quantity consumed. I think that a careful reading of the report of the company tests will indicate that the satisfaction with the heavier fuel was the same as with the lighter, but we have always sacrificed something to be able to use cars at all,

[1] Annual report of the Research Committee.
[2] M.S.A.E.—Consulting engineer, New York City.
[3] See The Journal, January, 1923, p. 3.

and we shall have to sacrifice something in our actual use of cars to allow of our getting the fuel to use them; there is no question about that.

To check-up on the result of the tests at the Bureau of Standards, a friend of mine ran a short test on a car that has a planetary gearset and a thermosyphon water-circulation. This car is fitted with a carbureter presenting about as good metering characteristics as are possible at present. It was first tested for acceleration, and then for road mileage, with two different grades of fuel. These two different grades tested 60 and 69 deg. Baumé respectively, one of them being the standard fuel in the district and the other a higher-test fuel which is also on sale regularly in the same district.

It is believed that both these figures are slightly high; but they are relative because the same hydrometer was used in both cases. Two tests were made in each case, one cold and one hot. With the heavier fuel, the water temperature was 87 deg. cent. (188.6 deg. fahr.) hot and 65 deg. cent. (149 deg. fahr.) cold, and with the lighter fuel about 80 deg. cent. (176 deg. fahr.) hot and 55 deg. cent. (131 deg. fahr.) cold. The most rapid acceleration obtained was from 10 to 20 m.p.h. in 6 sec. with a No. 4 setting on the lighter fuel with the cold engine. As against this, the time for the fastest acceleration with the heavier fuel was 7 sec., but it was obtained only with a hot engine, and with a setting 1 deg. richer on the carbureter. On the other hand, with the hot engine, the fastest acceleration with the volatile fuel was 10 to 20 m.p.h. in 6½ sec. I bring this last point out because it shows pretty clearly the reason why many of these service tests indicate so little difference between the different grades of fuel. We do not take advantage in the service tests of the ability to run colder with the fuel of higher volatility and thereby obtain greater power from the same engine. This is clearly brought out in this test, because the difference is very marked between the maximum acceleration possible with the high-test fuel when the engine is cold and the acceleration with the engine hot.

Road Tests

A number of road tests were made with different carbureter settings, again using the different fuels and the two temperatures. The greatest mileage obtained on 1 pint of fuel at an average speed of about 18 m.p.h., on a rolling road surface with grades up to 4 per cent, was at the rate of 32.8 miles per gal., using the lighter fuel, which is very far beyond the average mileage shown in the Bureau of Standards tests. The highest rate obtained with the heavy fuel was 28.8 miles per gal. On the other hand, with the carbureter setting of 5, with the engine hot in both cases, the mileage per gallon was exactly the same, 19.2. The two other figures obtained indicate clearly that the average owner, if at all careless of carbureter setting, might easily get worse mileage with the more volatile fuel.

I am not presenting those figures as an argument for using 69 deg. gasoline. I would rather use it myself, I will admit. But I think the figures indicate somewhat why the results that were obtained last summer were obtained, and also that they emphasize the possibility that the general public, not the skilled drivers, will do about as well with the heavier fuels as with the lighter one, so far as road mileage is concerned. That, after all, is part of our investigation. I still believe that, in a car especially adapted for the lighter fuel, we can show substantially better results with the light fuel than we can with the heavier one; but, in a car adapted for the heavier fuel, the light fuel will show no great road-mileage advantage, up to a fuel heavier than we have today.

I regret to say that, in our own industry, there is a trend in engine design which will be hard to satisfy with heavier-grade fuels. That is an attempt to obtain high engine-power at high engine-speeds. This can be done only by the use of large carbureters with low depression, by large manifolds and valve-ports, and all of these things are the worst possible adjuncts to a proper handling of a fuel of low volatility. Every airplane participating in the 1922 Pulitzer Race used, I believe, aviation gasoline mixed with 50 per cent of benzol. They did not consider the cost of the fuel at all; it was a question of performance, and they used what their experience showed would give them the best performance. The reason, in their case, why the performance is the best is that they operate with a cold engine, one as cold as they can get it, for the obvious reasons of an improved volumetric efficiency and a reduced tendency to detonate. With the large manifolds and large fixed-opening carbureters employed, a heavier fuel to obtain maximum power at high speed simply will not control. If the engine throttle is down and an attempt is made to open it up suddenly, the engine just dies; it will not operate. I say that I regret to see that our own industry seems to be pointing a little toward a type of design that does not go satisfactorily with the type of fuel that we probably will have to use. At the same time, I wish to call attention to the fact that the automotive engineer is being forced to design engines of less overall operating flexibility to cope satisfactorily with less volatile fuel. Fortunately, the great majority of both truck and passenger-car users do not require, in regular service, any such wide range of flexibility as can be obtained with fuel more volatile than is being supplied today.

Continuation of Tests

I said earlier in this talk that I consider that we have not finished the investigation of fuels. We have made a summer test, and know something of the probable result of summer operation. I think that we should also have a cold-weather test to complete the cycle, where conditions are possibly fairly extreme. I do not ask for extreme weather-conditions simply to try to put over a point of view on the oil people. I think that we can be trusted to assess fairly the amount of cold-weather and hot-weather running that has to be considered; but we all know that it is often wise to make an extreme test in making an experiment to get an idea of the general trend of things; we can go from an extreme to an intermediate test after we have established a general trend, while we may cloud the situation entirely by making an intermediate test with minor variations only.

For instance, we might start with a gasoline of 300-deg. end-point and raise the end-point 10 deg. at a time, allowing a driver to test first one and then the other. I think we might get him up to a gasoline with a 500-deg. end-point by such steps, and at every step challenge him to tell which was which. It is obvious that, even if he could not tell a difference in the operation at each of the intermediate steps, that would not mean that he could not easily tell the difference between a gasoline of 300-deg. and one of 500-deg. end-point; we would simply have been making the steps too short to cover the inaccuracies of observation or of measurement. That is the way I feel about the cold-weather test. I would like to see it made under such severe conditions that it

will show something very definite beyond the possibility of argument as to what it means. I think I can say for the automotive industry that it will be glad to assess the test on its value as a test, including the temperature conditions, and be willing to reason from that back to what the normal average temperature conditions are.

Fuel Volatility

In relation to fuel volatility, we have heard considerable talk about crankcase-oil dilution. I look on crankcase-oil dilution to a considerable extent as a ready means of determining what the fuel volatility is doing in the engine. In other words, it is one of the few things that changes extremely with moderate changes in volatility. In the Bureau of Standards tests and those at Detroit, this was the one thing that showed-up plainly on all the cars as a variant with the use of the different fuels involved. From that point of view it is an interesting test; but, as a member of the automotive industry, I think that, from its actual effect on the operation of the engine, we are not ready to go to the mat with the oil people on the basis that a certain percentage of crankcase-oil dilution is a certain proof that a type of fuel is inadmissible. I would find it very hard to try to prove that mixing 10 per cent of kerosene with the oil generally used in any of our engines would upset the lubricating system or wear the engine out prematurely.

Judging from data in my possession, I think we can not blame all the wear that takes place in automobile engines on crankcase-oil dilution. The data refer to a car that has been, I think, about 90,000 miles; the owner says 150,000 miles. It was examined personally by me 3 years ago and showed no measurable wear in the pistons, cylinders or rings, and not sufficient wear in the main or the crankpin bearings to justify any work. The owner did not ask about getting a new carbureter or a new manifold, or whether he ought not to stop the oil-pumping, or whether he needed new rings or pistons; he feared that, possibly, the old machine was getting tired-out and ought to be put on the shelf. The data simply show that a car will operate for long periods on standard every-day gasoline, undoubtedly with a certain proportion of crankcase-oil dilution, without wearing-out.

As I said previously, we may be able to use crankcase-oil dilution as a ready means of measuring the probable general effect of too heavy fuel; and, for that purpose, I think it has its advantages. But I think that we cannot safely take the ground that it upsets the lubrication of the job in such a way as to make the use of a fuel causing a certain percentage of dilution out of the question or even economically impossible.

Quoting from Mr. Gottschalk's paper, under the head of Drivers' Comments,[4] I have been told many times that nobody can tell the difference in the service obtained from fuel by the degree of satisfaction of the driver; I do not mean as to road mileage, but whether the drivers like it. The quotation is:

> Three of the cooperating companies inserted their drivers' comments on the relative performance of their cars with the separate fuels. The comments of these 25 drivers indicated that greater volatility of the fuel leads to a greater ease and satisfaction in driving, while a high-end-point gasoline, such as *D*, induces "spark-knock," slowness in warming-up, sluggish acceleration and other difficulties. One driver considered all four fuels about the same, and in two other instances only did the driver's order of preference not conform to the order of volatility, *A*, *B*, *C*, *D*.

I would like to have you look at the distillation curves of these four fuels, shown in Fig. 1 of the paper,[5] see how close they are together and then read that last sentence again. Practically 22 drivers, out of 25, were able to place these four fuels in their order of volatility by operating the car; and we are informed that the drivers were not told what fuel they were using. Also bear in mind that this test was run in summer.

In closing, I want to express the thanks of the Research Committee and of the Society to the companies that cooperated in this work: To the Buick Motor Co., the International Motor Co., the Ford Motor Co., the Packard Motor Car Co., Dodge Bros., the Studebaker Corporation of America, the Hupp Motor Car Corporation, the Willys-Overland Co. and the Stromberg Motor Devices Co.; also to the staff of the Bureau of Standards; and finally, to the American Petroleum Institute, which, as an organization, has worked with us. Further, we thank members of the American Petroleum Institute who supplied fuels for the tests; a great amount of special fuel was required. They furnished technical assistance and men to assist in the running of the tests also.

[4] See The Journal, January, 1923, p. 7.
[5] See The Journal, January, 1923, p. 3.

DETERMINING THE MAGNETIC PROPERTIES OF SHORT BARS

THE growing interest among engineers and designers in the correlation of the magnetic and other physical properties of iron and steel has given impetus to the study and development of methods for making the necessary magnetic measurements. Many materials of an experimental composition or of extreme purity are available only in limited quantities, and the ability to obtain magnetic measurements on small samples would be of decided advantage both from the point of view of economy of material and because of the ease of the machining and heat-treatment.

The direct determination of the magnetic properties of small samples with any degree of accuracy is a difficult matter, but the Bureau of Standards has recently developed an apparatus that is capable of measuring the magnetic properties of such a sample with a satisfactory degree of precision. The method involves the comparison of a sample of the material to be tested, which is in the form of a cylindrical bar 6 mm. (0.23622 in.) in diameter and 10 cm. (3.937 in.) long, with a reference bar, the apparent magnetic properties of which have been determined through calibration by standard bars having accurately known properties. This method is capable of giving results within 5 per cent for most materials. As the accuracy depends, to some extent, upon the degree with which the properties of the test bar agree with those of the standard bar used for the calibration, the range of materials that can be tested with satisfactory accuracy depends upon the range of properties covered by the series of standard bars.

Over-Loading of Motor Trucks[1]

By David C. Fenner[2]

EFFECTIVE regulation can be accomplished only after a careful investigation and determination of the direction and amount of deviation from standards of normal practice. When we attempt to determine the facts regarding the loading of motor trucks we are handicapped by the lack of a standard that can be used as a practical basis of comparison. A motor truck is a carrying tool but not necessarily a measuring tool. It should be placed in the same general classification with the shovel and the wheelbarrow and not with the quart and peck measure and the bushel basket.

The over-loading of motor trucks is due in part to the improper basis of rating and classifying the motor-truck chassis in terms of the builder's rated pay-load capacity. The user soon learns that this rating really does not mean anything. He purchases a motor-truck chassis, attaches a body that may or may not fit either the chassis or the commodity to be carried, and then loads the truck to suit himself. It would seem, indeed, that the motor-truck body is the real measure of capacity that determines the size of the chassis that must be used to carry it, loaded with the commodity to be hauled.

In the sale of motor transportation, the successful salesman conducts a careful survey, the results of which convince the customer that a certain type, size, capacity and weight of body are necessary to fill his transportation requirements. Then he is in a position to sell the customer the proper type and size of chassis to carry this body loaded to capacity with the particular commodity that it is purchased to haul. The large number of misfit motor-trucks on the road today are the best possible examples of the other method of selling the motor-truck chassis first and allowing the customer to put on the chassis any body and to load it in any way.

Each chassis, when it leaves the builder's plant, has a definite rated capacity for both the body weight and the weight of the load. If a particularly heavy body is mounted, or various forms of auxiliary power devices mounted in addition to the body exceed the body weight-allowance determined by the chassis builder, the pay-load capacity must be reduced accordingly. In the case of dump-bodies with hoists and transmission power-take-off, power-driven winches, pumps, air-compressors and various other forms of auxiliary power devices, this excess weight is considerable, and in many cases over-loading would be reduced if a larger-capacity chassis were used.

Manufacturers have suggested that State motor-vehicle commissioners should refuse to license any truck that is not equipped with a manufacturer's caution-plate properly specifying the actual weight of the chassis and the body and the load capacity. They are now proposing to go a step further and indicate on this plate the maximum allowable gross-load for the front axle and for the rear axle, the maximum allowable speed and the distance in which the vehicle when loaded to capacity can be stopped with each set of brakes operated independently with the vehicle running at the stated maximum speed on a hard, dry, level roadway. The information on this caution-plate will give the owner the data he needs for painting the weight and carrying capacity on the sides of the vehicle to comply with the State law. It will also enable the local enforcement officer to check the distribution of weight between the axles, the maximum speed and the condition of the braking system. A similar plate for use on home-made trucks can be issued by the State motor-vehicle department. The information contained on this plate will prevent the operation of improper trucks and force the proper operation of good trucks. It will put the penalty for poorly adjusted brakes and steering connections directly up to the operator, where it belongs.

The man who over-loads to take advantage of the "overload capacity" offered by some truck salesmen encounters the general law of averages. In the end he gets just about what he pays for and no more. Invariably, the owner who follows this practice keeps no operating costs that are worthy of the name. The man who persists in wilful over-loading in the face of all the facts is a menace to public safety and should be refused permanently either a vehicle or an operator's license. He has forfeited his right to use of the highway. A few less of his kind on the highway will be a distinct benefit to highway transportation.

Joseph F. Whelan, one of the most progressive and successful professional truck-operators in New York City, says

> With regard to the perpetual statement that the regulation of loads to the builder's rated capacity would put the truckmen out of business, I would say that this is not so. Such regulation would help them materially. If it did nothing else, it would bring to a halt the activities of the irresponsible operators who have no regard for either their mortgaged equipment or their legitimate competitors.
>
> Truck-load regulation would mean that prices could be standardized and much equipment that is now idle operated at a fair profit, because additional trucks would be needed to carry the freight formerly piled haphazardly upon two or three long-suffering and much-abused vehicles.

Investigations conducted in some of the States show that the light and medium-capacity vehicles are over-loaded to a greater extent and in greater numbers than the heavy-capacity vehicle. This indicates the importance of restricting loads per inch width of tire per wheel and per axle. We must recognize the four classes of tire; pneumatic, cushion, solid-rubber and metal; in regulating speed and the determination of license-fees according to wheel-load. We must restrict the minimum thickness of solid and cushion tires when measured between the tire flange and a flat metal surface on which the wheel stands. We must also take into account the condition of the tire.

The safety of the public, the preservation of the highway, the economy of vehicle operation, the status of the operator and the successful and economic development of highway transportation all demand that the practice of over-loading should be discouraged, forbidden, prohibited and stamped out completely.

Put it up to your local motor-truck association to stop the practice of over-loading or take the consequences of a concerted action of the local automobile-owners' association and the local chamber of commerce to report to the enforcement officers every truck that shows the slightest evidence of being loaded beyond its capacity.

Take all the satisfaction out of over-loading. Then the man who has been over-loading just to beat the game will quit and the chap who is really forced by circumstances to haul more than the rated capacity of his present vehicle will buy a larger vehicle or a trailer. With a semi-trailer he can double the capacity of his present vehicle; by distributing the gross load over six wheels he can keep within the wheel weight-restrictions of the State law and the builder's rated capacity of the truck and help to preserve the safety of the public and the best interests of highway transportation.

The motor-vehicle industry stands solidly behind the rigid enforcement of the provisions of the Proposed Uniform Vehicle Law and the existing State laws. It condemns over-loading and over-speeding unreservedly, and will cooperate actively in every movement to regulate loads and speeds of motor trucks on the highway.

[1] Presented at a joint session of north central division of the National Highway Traffic Association and the Michigan State Good Roads Association, at Grand Rapids, Mich.

[2] Manager of the public works department, International Motor Co., New York City.

Society's Research Sheds New Light on Fuel Problem

By V. H. Gottschalk[1]

Annual Meeting Paper

ADDITIONAL data on another group of four cars were received too late for inclusion in this paper when it was printed in The Journal. The data are now appended in supplementary form, together with the discussion that followed the presentation of the paper. For the convenience of the members, a brief abstract of the paper precedes the discussion, with a reference to the issue of The Journal in which the paper appeared, so that members who desire to refer to the complete text as originally printed, and the illustrations that appeared in connection therewith, can do so with a minimum amount of effort.

ABSTRACT

THE author describes a series of road service-tests, made of stock cars driven by their usual drivers when using fuel of specified grades, to determine the effect of any changes in the fuel volatility on the gasoline mileage for the respective make of car as part of a general research program undertaken jointly by the automotive and the petroleum industries. The object was to determine the best fuel as regards volatility, from the general economic standpoint, and what grade of fuel will afford the maximum car mileage per barrel of crude oil consumed in its production.

Factors influencing the selection of cars used are enumerated and the fuels tested are discussed, together with general comment and a description of the test procedure. The results are tabulated and commented upon at some length, inclusive of descriptions of the methods. A summary of the results is presented in the form of conclusions that are stated in four specific divisions. The value of statistical research is illustrated by the results obtained. [Printed in the January, 1923, issue of The Journal.]

SUPPLEMENTARY DATA

The additional data received apply to another group of four cars. The figures for gasoline and oil mileages obtained with these four cars are given in Table 5, which supplements Table 2 of the paper and corrects the averages to comprise the results of all 59 cars. This report of the tenth and last cooperating company brings the total mileage of the test up to 61,114 and changes the average of the 223 test-periods to 274 miles each. To include the new figures, Table 1 of the paper should be modified so that lines 2 to 8 of the second column will read 63, 74, 42, 17, 4, 1 and 5.

The new figures change the oil mileages less than 1 per cent. The gasoline mileages show a slightly larger maximum-difference, 1.9 per cent instead of 1.6 per cent as previously obtained, and they are higher than for the original 55 cars. The car numbers given in the first column of Table 5 have been chosen to indicate the position of the additional four cars as regards the increasing order of Grade-*B* gasoline mileages. It will be noticed that they come at the bottom of the Table 2 of the paper and make a very welcome increase in the number of the high-mileage figures. The four new points to be added to each one of the three graphs of Fig. 4 of the paper will be found to lessen the degree of abnormality in the appearance of the high-mileage ends of the graphs.

TABLE 5—GASOLINE AND APPARENT LUBRICATING OIL MILEAGES

No. of Car	Miles per Gallon of Gasoline				Apparent Miles per Gallon of Lubricating Oil			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*
48—1	17.61	17.77	19.16	18.92	333	426	587	734
53—1	19.57	19.84	17.37	18.51	342	662	817	1,150
54—1	16.66	21.66	20.80	22.08	708	890	791	1,458
54—2	20.94	21.92	20.52	18.11	545	629	599	(*a*)
Average for 59 Cars...	15.09	15.33	15.04	15.05	631	755	792	927

(*a*) More oil at the end of the run than at the start.

Table 6 gives the data for these four cars as recalculated to show the number of ton-miles per gallon of gasoline. Table 6 is a new group. No. 13 is to be added to Table 3 of the paper. This is of questionable propriety because, besides some minor variations from the general scheme followed with the other groups, group No. 13 was tested in the period from Nov. 23 to Dec. 3, 1922, while the other 12 groups were run in the months of June and July, 1922. Nevertheless, we have calculated the averages of the group averages and the means, together with the deviations, and have included these numbers in Table 6 for comparison with the corresponding numbers in Table 3 of the paper.

Other additional data that have been received since the report of the company tests went to press is a fourth

TABLE 6—TON-MILES PER GALLON OF GASOLINE BASED ON A LOAD OF TWO PASSENGERS OF 150 LB. EACH

Group	*A*	*B*	*C*	*D*	Group Averages *A*	*B*	*C*	*D*	Expressed in Terms of *B* as 100 per cent *A*	*C*	*D*
13	22.9	23.9	22.4	19.8	...	...	...	...	...	...	...
	18.2	23.6	22.8	24.1	...	...	...	...	...	...	...
	19.3	19.5	21.9	20.7	...	...	...	...	...	...	...
	21.4	21.6	19.0	20.3	20.5	22.2	21.3	21.2	92.4	96.1	95.5
			Averages for 13 Groups		22.6	23.2	22.7	22.6	...	...	...
							Means for 13 groups		97.8	98.1	97.9
							Mean deviation of the mean		1.6	2.1	2.4
							Mean deviation of single observation		5.8	7.7	8.6

[1] M.S.A.E.—Research engineer, Society of Automotive Engineers, Inc., New York City.

TABLE 7—CRANKCASE-OIL DILUTION FOR SET 4, GROUP 9[b]

Fuel	A		B		C		D	
	Percentage Distilled Off[3]	Viscosity[4]	Percentage Distilled Off[3]	Viscosity[4]	Percentage Distilled Off[3]	Viscosity[4]	Percentage Distilled Off[3]	Viscosity[4]
	6.1	195	9.5	169	11.0	156	....	....
	4.0	230	4.5	215	8.0	155	11.0	145
	7.0	194	11.0	156	8.0	176	9.0	172
	5.0	217	4.5	212	5.0	194	7.8	193
	3.0	233	7.0	174	11.5	154	6.5	190
	.	.	....	....	20.5	97	....	....
Group Average.....	5.0	.	7.3	....	10.7	..	8.6	....
Average of the Groups Recalculated to Percentage Dilution.....	5.3	..	7.9	..	11.6	....	9.4	....

Original Oil

Specific Gravity	0.905
Viscosity at 100 deg. fahr., Saybolt sec.	303
Flash-Point, deg. fahr.	430
Fire-Point, deg. fahr.	495

[b] Table 4 of the paper should be corrected so that the Group Numbers in column 1 will read 10, 11, 12, 1, 2, 3, 7 reading from above downward.
[3] Dilution figures are given as percentage of gasoline distilled from the crankcase oil.
[4] Saybolt viscosity at 100 deg. fahr.

set of crankcase-oil dilutions belonging to this series and determined by the Bureau of Standards. These figures are given in Table 7 as a matter of record.

In conclusion, I take this opportunity to state that I am responsible for the calculations involved in the compilation of the data contained in the company reports, but that to Dr. H. C. Dickinson, research manager of the Society, belongs full credit for the conception of the idea and for the working plan of the statistical method as applied so successfully to the fuel research.

THE DISCUSSION

V. H. GOTTSCHALK:—The work reported in the paper is just one part of the cooperative fuel research. R. E. Carlson gives an outline of what we are trying to do in his paper on Economic Motor-Fuel Volatility.[2] We used the same fuel that Mr. Carlson dealt with, Grades *A*, *B*, *C* and *D*. In our case it was manufactured by a Western refinery, but the specifications were the same. If Fig. 1 of my paper is compared with the corresponding figure that Mr. Carlson gave, it will be seen that the curves are about the same. Our 10-per cent point was not so accurate as that which the Bureau of Standards had, but the end-points, or the spreads between the end-points, are about the same, I think. They are supposed to represent the same fuel and represent probably about what can be done in a gasoline refinery with reference to coming-up to specifications.

DR. VAN H. MANNING:—I am looking at the oil industry and at the automotive industry and I am watching the results of these investigations in an unselfish attitude of mind. Some difficulties to be encountered occurred to me when Mr. Gottschalk referred to the running of these tests by the average driver. Assuming that there are two drivers for every car in the United States, there are 24,000,000 people that you must educate to drive a car. I have been in educational campaigns for years, and I know how difficult it is to put these things over. I feel sure that, when these tests are finally concluded, you automotive engineers will get a satisfactory answer, an answer given by both industries, the two biggest in the world.

I want to take this opportunity of extending, on behalf of the oil industry, our appreciation of the splendid cooperation which we have had from the President, the General Manager and the Research Manager of the Society of Automotive Engineers, and from the National Automobile Chamber of Commerce.

[2] See THE JOURNAL, February, 1923, p. 139.

Cheaper Closed-Body Construction

By George J. Mercer[1]

Annual Meeting Paper *Illustrated with* Photographs

THE author quotes statistics relating to the proportion of closed to open bodies and outlines the changes that have taken place in body construction in recent years. He sketches the advances that have been made and states that the question to be answered now relates to what all this improvement in manufacturing methods has accomplished toward reducing the price of a closed-car body to the consumer. He compares the percentage of public benefit in 1922 with that of 1914, excluding the period of inflated prices immediately following the war, and states that it is 10 to 15 per cent, but says also that this is an unfair comparison because of the excessive increases in the cost of labor, lumber, sheet steel and trimming cloth.

An unconventional type of body, covered entirely with fabric over a foundation of wire-mesh and buckram fastened to the conventional wood-framing, is illustrated and described in detail, together with a statement of its advantages.

IN the news items of the trade journals and the automotive notes in the daily papers, continual statement is made that some one or other of the car builders is behind in the delivery of closed-body models. There are more than 1,500,000 closed-body cars in use in this Country at present, or 16 per cent of the total registration. In 1916 the proportion of open to closed cars was 1 per cent; in 1918, the output of closed bodies was 71,000; in 1919, it was 197,000, or 10 per cent; in 1921, it was 335,000, or 20 per cent, and the estimated output for 1922 is 635,000.

The increase in the use of the closed-body car justifies the statement that the closed body is superseding the open one as fast as reduced prices and manufacturing facilities permit. The open model will have its place, but will be more of the semi-racing or sport type and some one of the closed models will have to be featured in advertising, as the open body formerly was, to attract sales by its special value for the price. The problem is, how can a closed body be made much cheaper and yet retain approximately the present standard in appearance and service quality?

Changes in Body Construction

To arrive at a point of reasoning for the future, it will be well to review the changes that have occurred in body construction. Commencing with the all-wood body similar to that of a carriage, improvement was made by the substitution of sheet aluminum for the panels. During the time that aluminum was exclusively used, some companies made the panels of cast aluminum; the Pierce-Arrow Co. made all its bodies in this way for years. The next forward step was the use of sheet-steel panels. This was accomplished only after strenuous efforts, as neither the steel then available nor the machines for pressing and stamping were suitable for body requirements. The improvements since that time have been along the line of improved and more extensive stamping and drawing operations and, as a consequence, the labor of assembling has been lessened and some operations have been eliminated.

The all-steel body made by the Edward G. Budd Mfg. Co. for Dodge Bros., and used by the latter for several years, is a further advance from the conventional wood-frame and steel-panel construction. It has been limited, until recently, to the open types. Its advantage is not so much any strength that it has over that of the combination body, because the latter is all-sufficient for service, but that the body when assembled can have the bake-enameled, whereas the wood frame of the combination body will not withstand the high temperature necessary for baking.

The advantage of the enamel finish is easily established in view of the fact that practically all cars have mud-guards, splashers and, wherever possible, radiators and engine hoods so finished. The advantage of applying this finish to the entire surface of the body is very great. The feature of a durable surface is but one of the merits; another is the saving of time. The Dodge body is finished complete in 1 day. The cheapest painting job will take 5 days, while a paint operation that will stand-up for a season will take 12 days. Because the heavy initial-cost to install this form of manufacturing necessitates the continuance of one model for a long period without changes to absorb this cost, and also because the baking process is limited to black, this method is confined to companies who make a standardized product in large quantities.

In addition to the distinct manufacturing changes already enumerated, there have been other changes that have had an effect in reducing manufacturing costs. For instance, the bodies are smaller; formerly, nearly all bodies were seven-passenger, now the majority are five or four-passenger. The design of the body is simpler, the aim being to economize in material and labor by having straighter lines, less extreme radii in the rounded corners and curves, a less number of moldings, simpler door-hinges, duplicate glass-sizes, simpler trimming design, fabric roofs in place of solid panels and improved painting methods in which, by the use of the spray and drying ovens, the time of painting has been reduced from 4 weeks to 12 days. The conveyor has been adapted for body use in all departments, and has become as necessary in this work as in chassis assembling.

Advance Toward Simplified Construction

At present, the advance toward a simplified construction that will reduce manufacturing costs is to make the body complete in sections and to ship it in knocked-down shape. This method, which is still in a partially experimental stage, will develop rapidly.

The question we want answered now is, What has all this improvement in manufacturing actually amounted to in reducing the price of the body to the user? Leaving out the post-war period of inflated prices, and comparing 1922 with 1914, the public benefits to the extent of a flat average of from 10 to 15 per cent; but this is not a just comparison because labor is paid 100 per cent more, and lumber costs 77 per cent more, sheet steel 43 per cent more and trimming cloth 80 per cent more. These

[1] M.S.A.E.—Consulting engineer, Detroit.

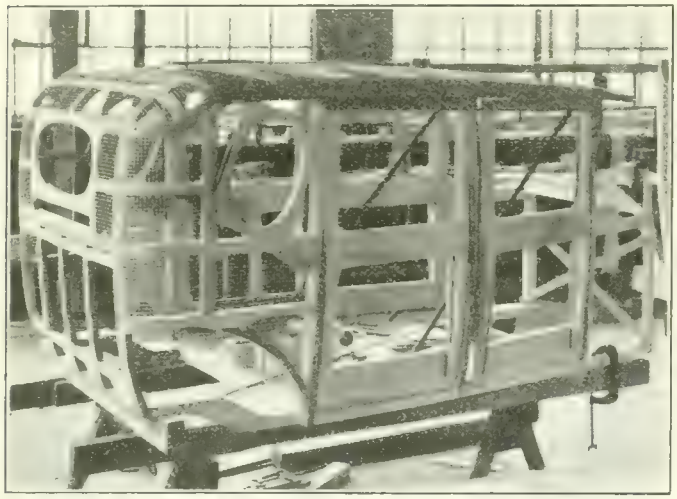


FIG. 1.—FRAMEWORK OF THE BODY AFTER THE NO. 19 WIRE MESH HAS BEEN APPLIED

items show what the body builder is up against; what his problem has been, and is, of how to market an article for less money and yet pay more for material and labor.

One other item is to be considered: Style or design. The appearance of the body is so important that car-sales are made or lost in accord with this feature, provided the other parts of the car are equal in merit. Consequently, this elemental part of the body, that appeals to the artistic sense of the purchaser, bulks large with the selling organization and is a determining factor in production.

To sum up, closed bodies must be produced more cheaply, and have a sufficient amount of style to attract favorable attention, minimize sales resistance and make commensurate advertising expense worthwhile. In addition, they must be of light weight; recent data show that 71 per cent of passenger-car sales are confined to the medium and low-priced small-cars. In Europe very light small cars, designed to minimize upkeep and operating expenses, are being made. Since 1916, although the Ford Motor Co. has increased its output, its proportion of the total volume of business in the less-than-$1,000 class has constantly decreased.

AN UNCONVENTIONAL TYPE OF BODY

At the time I was asked to write this paper, I had in mind the sectional-finished body with its possibilities of finishing complete in easily handled parcels, by this method, saving in shop space and allowing cheaper transportation expenses and the speeding up in production. But I had thought of this only as a metal-panel body, until K. L. Childs, of the Standard Textile Products Co., gave our firm an order to make a body to demonstrate the practicability of covering a body entirely with fabric over a foundation of wire and buckram fastened to the conventional wood-framing.

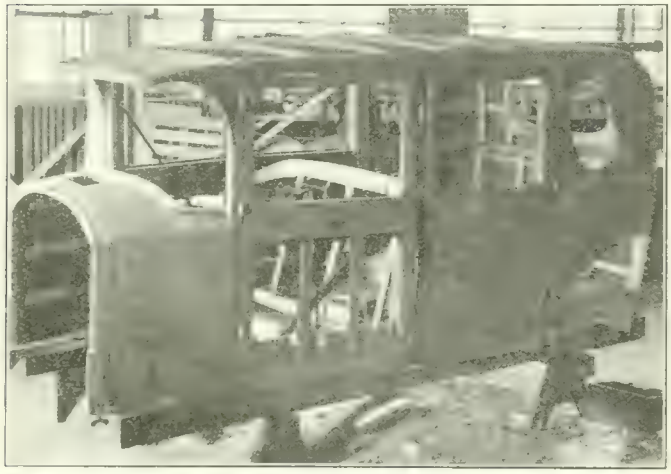


FIG. 2.—THE WIRE MESH IS COVERED WITH A LAYER OF COTTON WADDING AFTER WHICH BUCKRAM IS APPLIED

This idea is not new in its entirety. Fabric has been used for body covering by shellacing the fabric over the steel panels. Reports of its wearing qualities have been uniformly satisfactory. We are familiar with the California top; and this, too, has given uniform satisfaction when a good quality of fabric material has been used. The service that the fabric top has given is generally known; so, there is a fair background of experience upon which to base one's judgment as to the practicability of making a real fabric-covered body, eliminating the steel under-panels and using a foundation that is cheaper, lighter and more easily and quickly applied, yet having sufficient rigidity to retain the shape when molded.

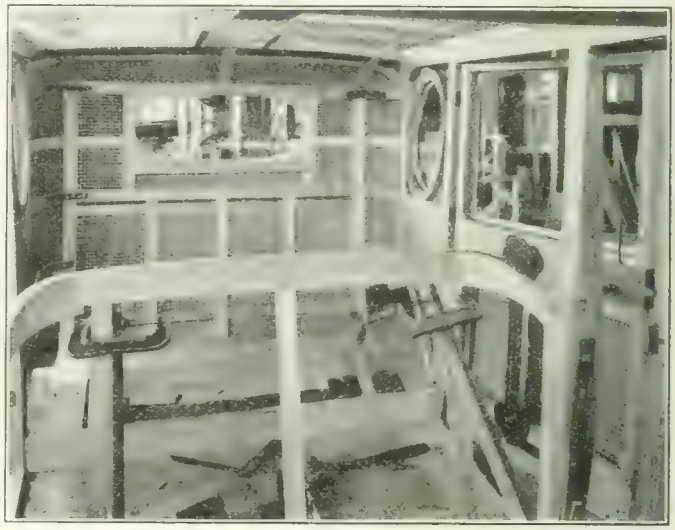


FIG. 3.—AN INTERIOR VIEW OF THE BODY AFTER THE BUCKRAM HAS BEEN PLACED

The illustrations presented show the progressive steps in making this sample experimental body. They are to be considered as indicative of experimental or research work only. The application of this principle to the conventionally designed body, whereby we plan to make it cheaper and lighter, is now under way, and we expect to be as successful as we have been with this sample of expensively designed coach-work.

Fig. 1 shows the application of the wire to the framework. This is a No. 19 gage, 2 meshes to the inch, and fastened with staples. Fig. 2 shows the buckram fastened over the wire. One layer of cotton wadding is placed between the wire and the buckram and the framework is double-rabbeted, one rabbet being for the wire; the one for the buckram is wider, so as to have it cross the joint and be nailed beyond the wire edge. Fig. 3 is a view of the interior of the body, and Fig. 4 shows the body with moldings tried-on and ready for the fabric covering, which is shown applied in Fig. 5. It will be noted that the door and window openings have rounded corners; this is necessary to allow the fabric to be carried over and fastened to the inside without cutting the

goods to fit a square corner, as would otherwise be necessary.

Fig. 6 shows the finished body installed on a Packard chassis. A. L. Knapp, of the Packard company's engineering department, is to be credited with some of the original initiative prior to actual construction of the body. Fig. 6 does not do justice to the body, owing to haste of work preparatory to shipping.

The illustrations show an absolutely new method of body construction. This is the first body that has been made using fabric entirely for the panels. It is the most radical innovation in body construction that has been introduced since the advent of the motor car. Moreover, the initial idea and the first experimental work were by a man who is not a body-builder. I feel in duty bound to give credit to Mr. Childs for having the courage of his convictions and providing the money to try-out his theory.

Practical Considerations

Considering this form of construction from the practical point of view, let us consider the appearance first. The most expensive bodies, those that are built for the highest-price trade, have the top, upper back and rear side-quarters of leather. We can remember that in the carriage days the leather Victoria-top added a charm to the body design that has never been equalled. The high-finished, long-grain landau-leather used always adds a satisfying finish to the body. These comparative statements regarding leather refer, of course, to the conventional form of using it, in which part of the body is

Fig. 4—Exterior of the Body with the Moldings Temporarily in Position and Ready for the Fabric Covering

painted. The subject of this paper is a body that is covered entirely with a fabric that is a perfect duplicate of landau leather. Therefore, it will be necessary to show it to the public before the idea can be realized completely.

The point that the public probably will be most skeptical of is durability. The matter of durability has two angles. First, regarding the lasting quality of the finish, the experimental product has withstood the test of all weathers for 2 years; it is still in daily use, and the foundation of the coating is so well preserved that a little friction with a soft cloth will brighten it so that it looks almost like new. The care to keep such a body

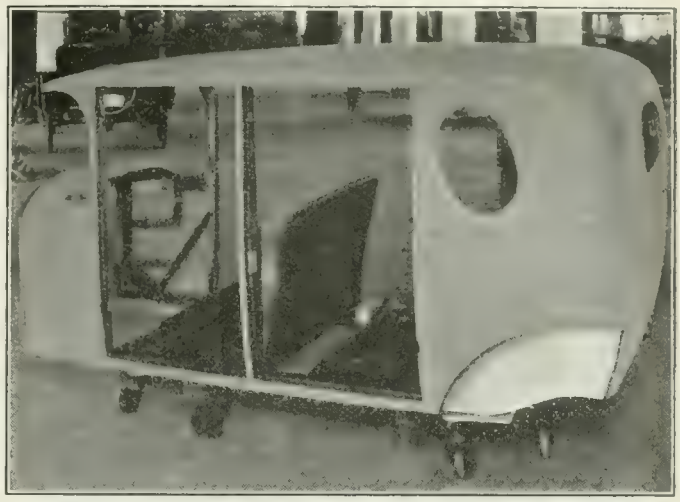


Fig. 5—The Fabric Covering Applied

looking fit is as nothing when compared to what is required for a painted surface; it does not need to be washed, but simply to be dusted-off with a cloth and, occasionally, to have a little polish rubbed-in. The other angle respecting durabiliity is whether a body so made will stand-up in average use. Lapse of time will be required to ascertain this.

In working on this body, no thought was given to the fact that the construction was exceptional. We know that, in all body construction, extreme rigidity is a "weakness." We must provide for compensation to take care of the weave, just the same as is done in bridge building; so, any form of body construction will stand-up that will absorb the shocks and return to its original shape after distortion. We believe that this form of construction has wearing qualities that will surpass those of many of the metal-panel bodies now made. It is reasonable to say that it will make the ideal all-season body, because the fabric covering should be warm for winter use and, in summer, as there is no medium to conduct the heat, it may prove to be equally as serviceable as the body that is composed of metal panels.

The weight of a body made as illustrated is slightly less than that of an aluminum-panel job. The weight of the combined wire, buckram and fabric is less than ¾ lb. per sq. ft. Aluminum construction weighs approximately ⅞ lb. and steel 1½ lb. per sq. ft. The size of the wood framing is the same as for aluminum or steel construction; the steel body-braces are likewise the same, as also are the doors, roof and windshield. In designing, we made no addition to the construction above that required for the conventional light-weight metal-panel body,

Fig. 6 The Completed Body Mounted on a Chassis

and we are confident that we have given our customer a serviceable body.

The flat cost of the covering and foundation material on this sample body was 26 cents per sq. ft. Aluminum would cost 30 cents, and steel, 7 cents per sq. ft. To the cost of both aluminum and steel construction stamping or hammer costs must be added, as well as the costs of finishing and then painting. In 6 weeks from the time of receiving the order, this body was completed and on its way. This included considerable work that would not ordinarily be required; special mudguards, side splashers, spare-wheel brackets, trunk brackets and the like. The amount of the work of designing, and that of the mill work and framing, are the same as for the ordinary body, but a great saving is gained in finishing. Two men completely finished the exterior and the interior of this body in two weeks. The entire outer-surface work was finished first. During the time of completing the work I realized how different the conditions would have been if this body were made with a painted surface. At no time was it necessary to admonish the workmen to keep their hands off, and no special attention was required to protect the fabric surface; but, had the surface been painted, the care of the finish would have been of prime necessity. Even when it was put into the freight-car for transportation, the body was not covered; if this form of construction has no other merit than that of having a surface that is rugged and does not deteriorate from indelicate handling, it cannot fail to win its way into general use.

The body has one other commercial merit. Reference was made previously to the amount of time saved in enameling the surface as compared with painting. We make the same claim for the fabric-covered body. One day's labor is ample to cover the exterior of a body with fabric. This represents a gain of from 5 to 11 days, according to the quality of work. This form of construction has the merit of the combination body in that the process is flexible, and changes in design can be made without sacrificing expensive jigs and tools. Moreover, the form or shape of the body does not have to be considered as in the case of a metal-covered body, because the wire, buckram and fabric can be applied as easily to a rounded surface as to a straight one.

The question naturally arises as to why this method of making bodies did not come forward earlier, since efforts have been made to use leather cloth. I want to spread the information that the fabric so often called imitation leather should be called by its proper name, leather cloth. Leather cloth has been made in only the semi-dull finish until recently, and there was not sufficient luster in the black color to please the eye. The high luster that is now obtainable will compare favorably with that of the finest landau-leather; therefore, the psychological moment seems to have arrived to make use of the material in question for body covering. It will withstand more rough usage than a painted surface will, and remain presentable for 2 years; it can then be rehabilitated by varnishing with carriage varnish.

Actual Advantages

The actual benefits that we have proof of, with the limited experience of making one sample-body of the construction just described, are less weight of body than results from any other method of construction; a body that can be fabricated more quickly, because the finishing is equal in time to enameling, an absolutely sound-proof body, because of its shock-absorbing quality; a comfortable all-seasons body, and a flexibility in construction, not equaled in any other method, that will permit what have been considered expensive shapes to be made cheaply. We feel that we have demonstrated unquestionably, in this experimental job, that we have made a body that in finish, design and attractiveness will compare favorably with any body made by using the customary materials. Furthermore, we feel confident that production bodies can and will be made by this new plan, and that they will be cheaper and better looking, because there is not the necessity of having so many manufacturers follow the stereotyped fashion. It is possible, also, to use various colorings of fabric. Thus, all the benefits of former practice are at the command of the fabric-covered-body builder, as well as several additional advantages.

STANDARDIZATION OF OIL-FIELD EQUIPMENT

THE following resolution proposed by representatives of the Board of Directors of the American Petroleum Institute was unanimously adopted at the meeting of that organization held in St. Louis during the early part of the month of December:

Resolved, By the group session on standardization that it is their judgment that standardization, simplification and improvement of oil-industry equipment and methods is necessary and desirable and will result in great economics; and be it further

Resolved, That the Board of Directors of the American Petroleum Institute be requested to declare it to be the policy of the Institute to encourage and to bring about standardization and simplification of oil-industry equipment and methods where desirable and practicable and to this end that the Board of Directors of the Institute be requested to appoint such committees of the oil industry as may be advisable to carry on the work in cooperation with the executive staff of the Institute and with the various agencies already contributing valuable work on the subject, such as the American Society for Testing Materials, the simplification bureau of the Department of Commerce, Bureau of Mines and the Bureau of Standards

Standards Committee Meeting

THE reports of Divisions, as printed in the December issue of THE JOURNAL, with the exception of that on Rating of Storage-Batteries, were duly considered and acted upon by the Standards Committee at its meeting on Tuesday, Jan. 9, at which Chairman E. A. Johnston presided. Two reports, which are printed in this issue of THE JOURNAL, but had not been prepared prior to the issuance of the December number of THE JOURNAL, were acted upon. These related to revision of the present standards for Roller-Chains and Roller-Chain Sprockets, and a proposed Recommended Practice for Tail-Lamp and Registration Number-Plate Illumination by the Lighting Division.

The action taken by the Standards Committee was reported to the Council at its meeting immediately thereafter and to the Business Session of the Society the next day and approved for submission to the voting members of the Society for final letter-ballot on adoption by the Society as S. A. E. Standards and Recommended Practices. The regulations governing the casting and recording of the letter-ballots require that they be returned to the Society within sixty days following the Annual Meeting of the Society. The letter-ballots will therefore be counted on Monday, March 12.

In casting their letter-ballots, Members should refer to the reports as printed in the December issue of THE JOURNAL, commencing on p. 529. In the discussion of each report that follows in this issue, each subject, with its page reference only, is given except for reports that were revised and the special reports mentioned in the foregoing paragraphs.

The session was opened with 42 members in attendance by Chairman E. A. Johnston. He first introduced Calvin W. Rice, secretary of the American Society of Mechanical Engineers, who gave a short talk on the International Engineering Congress recently held in Brazil. In introducing Mr. Rice, Chairman Johnston said in part:

> We are assembled at this session of the Annual Meeting of the Society to receive the reports of Divisions covering the work that has been passed upon by them since our meeting last June. Some of these reports are of extreme importance and will require considerable time for adequate discussion before passing upon them.
>
> As is well known, this Society was one of the earliest proponents of engineering standardization, and has fostered this work industrially for many years. Within recent years there has grown up a broader appreciation of its great value to the industry, so that now our work is national as affecting all of our industries and is very rapidly receiving serious international consideration. We should keep as well posted as possible regarding the international situation in order that our efforts may be adequately helpful and that the greatest benefit to all industries may be had.
>
> Calvin W. Rice, secretary of the American Society of Mechanical Engineers, who was a member of a mission from the United States which attended the International Engineering Congress in Brazil recently, has kindly offered to make a few remarks regarding the international standardization movement as brought out at the conference and as to the status of standardization in foreign countries. It is a pleasure to introduce Mr. Rice to you.

Mr. Rice spoke as follows:

Not only is the prosperity of your industry, but of this Nation, dependent upon the work that you are doing in standardization.

The United Engineering Societies joined in making me a delegate to the International Engineering Congress and I took advantage of that trip to make a tour of South America and call upon all of the engineering societies. Having been active in the Inter-American High Commission, I sought a commission from Secretary Hoover, so that the Inter-American Commission might be a factor for good in the nations that form the Pan-American Union. He was glad to do that, and gave me a letter to the Minister of Finance of each nation.

After we arrived in Brazil, I saw one of the elder statesmen, who said, "Why do you not have a suggestion for standardization come from the Congress?" So it was put through as a resolution of the International Engineering Congress, that standardization, elimination of waste, simplification of product, all known throughout the world as examples of American enterprise, should be introduced in the countries of the Pan-American Union. As you know, in Germany they have a word "Amerikanische," which means "the American method of doing things." This much has been accomplished.

Verne Le Roy Havens, the editor of *Ingenieria Internacional*, a Spanish publication of the McGraw-Hill company, has been the permanent secretary of the International Engineering Congress, and he will write all the governments of the 21 countries forming the Pan-American Union, advising the organization of standardization bureaus in each of them. None exists except in our own.

PROGRESS OF STANDARDIZATION IN SOUTH AMERICA

I am happy to report that since I have returned Brazil has acted, and last week I received a letter announcing that they had cabled to Secretary Hoover for the loan of Dr. W. E. Emley, who is down in Rio de Janeiro now, representing the Bureau of Standards in connection with its exhibit at the Exposition. I assume there is no doubt the Government will loan Doctor Emley to assist Brazil in establishing a Government bureau on standardization.

I uniformly called on the ambassador in each nation and explained the mission; then on the engineering society; then on the president of the local engineering society, and, in the case of Argentina and of Cuba, where we have associations of members of engineering societies of the United States, I took the presidents of those associations to call on the government. We proposed to the government in each country that they organize a bureau of standardization, for the benefit of that country. Then I got the officers of the local societies and of our own organizations to pledge to the respective governments their services, in the same way that this Society renders service to this Nation through its Standards Committee.

I want you all to feel, and you should tell the companies you serve, if you are officers of companies, that they ought to furnish the funds gladly, either by appropriation or paying the expenses, and allow the time of your staff to attend meetings of your Standards Committee Divisions, because you are promoting the prosperity of this Nation. If the Nation is prosperous, your industry will be prosperous. That gospel was preached in every country in South America.

People have been going to South America for 400 years to exploit the country. Pizarro, when he conquered Peru, for his first ransom on the head of the Inca chief who gave a banquet in his honor, exacted $15,000,000 gold, taken from the temples which that Inca chief had; and then after he had obtained that money, Pizarro murdered that chief and 1000 of his chieftains in cold blood. That is the worst story of perfidy in all history, but there have been lesser visits and methods all these years. I want you to feel that, for once, a different type of mission went to South America; that the engineering profession, represented by the citizens of the country and by our representatives who go to these countries, either temporarily or permanently, shall contribute their talents to the welfare of that nation.

It is to be expected that Mr. Havens, in his capacity as Secretary of the International Congress, will notify officially each country of this resolution of the Congress, favoring the establishment in each country of a bureau. Tomorrow morning I am to make my official report to Secretary Hoover, and, at my suggestion, we will meet in the Pan-American Union with all those departments of the Government that have anything to do with South America. There will be the Pan-American Union, the Inter-American High Commission, the Bureau of Latin Affairs of the Department of State, the Bureau of Foreign and Domestic Commerce of the Department of Commerce; then I hope that by invitation the Bureau of Standards will be there, and also the Bureau of Simplified Practice of the Department of Commerce and the American Engineering Standards Committee. I hope to pull all of those forces together and establish, gradually, commencing with Brazil, these standardization bureaus. Just think how fortunate it is, that within two months the thing has been actually started and the United States has been officially invited to furnish a man to instruct the government of Brazil how to do it.

I want you to feel, secondly, that there is no one thing in the whole world so important as foreign relations. The whole world is looking to the United States, and nothing could be better than for the engineering profession to be one of the groups of citizens of the world to have a definite job, like standardization. It is of enough importance to be worthy of all of your energies and, as you go ahead in your work of standardization, I want you to feel that you are helping this Nation to be prosperous and helping to bring all nations closer together and, if possible, make war unthinkable.

In proposing a vote of thanks to Mr. Rice for addressing the meeting, C. F. Clarkson pointed out the increasing importance of our trade with South America, relatively speaking, in our foreign commerce. He also spoke of the sincere and generous feeling on the part of Mr. Rice for the Society, who is, in his opinion, a very keen and good judge of economic values in the professional field.

Action on Division Reports

The following tabulation indicates the recommendations, presented by the different Divisions, that were accepted at the meeting of the Standards Committee and approved by the Council, and also by the Society at the Business Session of the Annual Meeting for submission to the voting members of the Society by letter-ballot. For subjects that were approved as printed in the December issue of THE JOURNAL, page references to that issue only are given. The additional reports that were presented at the Standards Committee meeting are printed in this issue of THE JOURNAL, as are also statements of the changes that were made in certain of the reports. These should be noted in the reports published in the December issue of THE JOURNAL.

REPORTS ACCEPTED AND APPROVED

Axle and Wheels Division

Passenger-Car Front-Axle Hubs — p. 529

Chain Division

Roller Chains and Roller-Chain Sprockets — Printed in this issue

Electric Vehicle Division

Electric Vehicle Motor Rating — p. 535

Electrical Equipment Division

Generator Flange-Mountings — p. 536
Starting-Motor Flange-Mountings — Outboard Type — p. 536
Starting-Motor Flange-Mountings—Inboard Type — p. 537
Starting-Motor Pinions — p. 537
Magneto Mountings — p. 537
Spark-Plugs — p. 537

Engine Division

Flywheel Housings — p. 538

Frames Division

Running-Board Brackets — p. 539

Iron and Steel Division

Iron and Steel Specifications — p. 539

Lighting Division

Electric Incandescent Lamps — p. 539
Tail-Lamp and Registration-Number-Plate Illumination — Printed in this issue

Lubricants Division

Crankcase Lubricating Oils — Revised at meeting

Nomenclature Division

Automobile Nomenclature — p. 541

Parts and Fittings Division

Plain Washers — p. 541
Rod-Ends — p. 542

Passenger-Car Body Division

Door Locks and Handles — p. 542
Wood Screws — p. 542
Plate Glass — p. 542

Screw-Threads Division

Gages and Gaging — p. 543

Storage-Battery Division

Rating of Storage-Batteries for Isolated Electric-Lighting Plants — Revised at meeting
Storage-Battery Monobloc Containers — Revised at meeting

Transmission Division

Clutch Facings — Revised at meeting

Truck Division

Vertical Dumping-Hoist Platforms — p. 546
Three-Joint Propeller-Shafts — p. 546
Body Hold-Down Clamps — p. 547

In addition to the reports listed in the foregoing tabulation, a progress report on Differential Gears was submitted by the Axle and Wheels Division, the Truck Division presented the report on Motor-Truck Cabs that was printed on p. 547 of the December issue of THE JOURNAL, as a progress report, and the report of the Ball and Roller Bearings Division on Metric Type Thrust Bearings, that was printed on p. 536, was referred back to the Division.

The discussions on all of the reports presented at the Standards Committee meeting are printed below.

AXLE AND WHEELS DIVISION REPORT

Passenger-Car Front-Axle Hubs

(*December issue of* The Journal, *p.* 529)

THE DISCUSSION

C. C. Carlton:—This report, which embodies a year's work, can be discussed very briefly or at great length, as you wish. A year ago standardization of truck front hubs as S. A. E. Recommended practice was accomplished. This proposed S. A. E. Recommended practice is for passenger-car front-hubs. It follows current practice very closely, and is not an attempt to set up a final S. A. E. Standard. It is largely a compilation of current practice into a recommended practice rather than the ultimate of what can be accomplished in passenger-car hubs. We wish to call particular attention to the personnel of the Division and Subdivisions that have worked it out, because practically every manufacturer of the article in question is represented therein.

The ball-bearing hubs have not yet reached the point where they can be standardized.

CHAIN DIVISION REPORT

Roller Chains and Roller-Chain Sprockets

(Proposed Revision of S.A.E. Standards)

This report, which relates to two subjects, was finished after the December issue of The Journal was printed. It is the result of several years' work done jointly by the Chain Division and the Transmission Steel Roller-Chain Committee of the American Society of Mechanical Engineers and its technical subcommittee. The art of designing and manufacturing roller-chains and their sprocket tooth-forms has been studied very carefully by the chain manufacturers with the object of developing standards that would bring all makes of chains, sprockets and their cutters to a common basis and assure a high quality of product and satisfactory operation.

The report embodies revisions to be made in the present S.A.E. Standards shown on p. E3 of the S.A.E. Handbook. The revision will include illustrations of the sprocket tooth-forms and their controlling dimensions.

Much effort was made, particularly when the present standards were being formulated, to effect uniformity with British chain practice, but it has not been possible to accomplish this entirely, although with the standards as now developed interchangeable operation can be had where necessary. The principal differences between American and British practice lie in some of the chain widths and roller diameters and to some extent in the sprocket tooth-forms. Therefore

The Chain Division recommends that the present S. A. E. Standards for Roller Chains and Roller-Chain Sprockets, pp. E3 and E4 of the S. A. E. Handbook, be revised as follows:

Roller Chains

(1) The following note refers to the formula for minimum breaking-strengths:

Note.—These loads are those at which the chains may break or become permanently stretched. The actual *working* loads may range from 1/6 to 1/50 of the ultimate-strength, depending upon the speed, the number of teeth in wheels, the conditions of lubrication and the pulsations arising from either the power or the load end. Chains should not be selected on the basis of breaking-strength

(2) The Standard Measuring Load is to be changed from "1 per cent of the average breaking-strength" to "1¼ per cent of the *minimum* breaking-strength"

Reason.—The minimum allowable breaking-strength is given by a formula. The average breaking-strength is not

(3) The Test-Load is to be changed from "one-third of the average breaking-strength" to "40 per cent of the *minimum* breaking-strength"

Reason.—Same as in (2)

(4) The system of naming chain parts, p. E3c, is to be changed as follows:

Assembled Pins, instead of pin link, consist of *one* pin-link-plate assembled with two pins

Pin Link consists of *two* pin-link-plates assembled with two pins

Connecting Link consists of a pin link with one detachable pin-plate

Roller-Chain Sprockets

(5) The standard tooth-form for block and twin-roller chains shall follow the same specifications as those for a roller-chain tooth-form for the same angle of bend

(6) Recommended minimum cutter-diameters are to be as given in the table

(7) Recommended widths of cutters are to be as given in the table

(8) Revised tooth-form and cutter outlines are to be in accordance with given diagrams

(9) Minimum diameter of the sprocket blanks for roller-chains to be equal to $P\,[0.6 - (\cot 180°/T)]$

If it is desired to have the entire range of teeth produced by a single cutter brought to a sharp point, this diameter should be slightly increased

(10) Uniform designations for the four principal types of sprockets shall be

Type *A*—Plain-plate
Type *B*—Single-hub
Type *C*—Double-hub
Type *D*—Detachable-hub

THE DISCUSSION

W. F. Cole:—The first four sections of the report provide for a slight revision of the formulas and dimensions that have already appeared in the S.A.E. Handbook. (5) is really a corollary of (8).

(6) and (7), regarding certain dimensions of cutters, also follow as a corollary to (8) and if that is adopted they would naturally also be adopted. The tables simply list the dimensions that are worked-out from the diagrams.

(8) is in some respects the most important of all. Recently the Society adopted some standard tooth-forms that were published in the S.A.E. Handbook on pp. E4a and E5. Very careful consideration was given to the working portions of the tooth and no material change in them is desirable. The height of the tooth, however, which is a rather inconsequential element, was originally set somewhat arbitrarily, with the result that in working-up the cutter designs in detail it was found that the height of tooth first adopted, while readily produced with single-purpose cutters, restricted the use of certain hobs and cutters that it was desired to make to cover more than a single pitch as well as a range of teeth.

Having found also that the formula which we had adopted, and which was published in the S.A.E. Handbook, for laying-out teeth, does not readily lend itself to practical use, we have taken the opportunity when revising the height of the tooth to simplify the formula.

(9) is also really a corollary of the preceding sections.

(10) is a uniform designation for the four principal types of sprocket; Type *A*—plain-plate, Type *B*—single-

hub, Type *C*—double-hub, and Type *D*—detachable-hub. This is included in the report for the sake of uniformity in specifying these various forms.

ELECTRIC VEHICLE DIVISION REPORT

Electric-Vehicle Motor Rating

(*December issue of* The Journal, *p.* 535)

THE DISCUSSION

E. L. Clark:—The recommendation of the Electric Vehicle Division with regard to the rating of electric-vehicle motors was prepared to place all motors of different makes on the same rating basis. It is based on the standards of the American Institute of Electrical Engineers for the type of motor under consideration, the only difference therefrom being, as noted in the last paragraph of the report, that the time specification has been changed to a 4-hr. from a continuous basis, and the words "at normal rated load" added at the end of the second paragraph.

ELECTRICAL EQUIPMENT DIVISION REPORT

Before presenting this report, F. W. Andrew, chairman of the Division, stated that the Division meetings had been unusually well attended during the past year. At least two of the very large manufacturers who had not had members present heretofore had found that they could not afford not to be represented at the meetings.

Generator Flange Mountings

(*December issue of* The Journal, *p.* 536)

THE DISCUSSION

Leonard Ochtman, Jr.:—I do not know to what extent lock-washers are used under the shaft nuts. In many cases an S.A.E. Standard plain-washer 3/32 in. thick would be used and the shaft should be extended 1/32 in. so that the unit will not project beyond the end of the thread.

F. W. Andrew:—In that connection we were careful to canvass the gear and engine manufacturers. They told us that the shaft should not be even 1/32 in. longer. The lock-washer shown is a standard. Some sort of a bearing under the nut is necessary, probably in the form of a washer. It was the unanimous opinion of the Division, representing practically all the larger electrical manufacturers, that this is a very good standard.

E. W. Weaver:—Is not the plain washer thinner in all cases than the lock-washer for the same inside diameter, and would not this overcome the restriction?

R. S. Burnett:—There are three series of lock-washers; special-light, regular and special-heavy. The special-washer for this size has the same light thickness as the plain washer. The regular and special-heavy lock-washers are considerably thicker.

Edward Wallace:—I notice that the difference between *D* and *E* is about 1/32 in. If the 7/32-in. dimension to the cotter-pin hole were used, would the pin fit properly into the nut?

Mr. Andrew:—Yes. The reason for the 7/32 in. dimension is that every manufacturer without exception will want a center-hole in the shaft-end. It is not desirable to break through in drilling the cotter-pin holes because this breaks the drills. This point has been provided for and carefully checked.

Spark-Plugs

(*December issue of* The Journal, *p.* 537)

THE DISCUSSION

Mr. Andrew:—This report on spark-plugs was submitted to the Electrical Equipment Division by a Subdivision of which O. C. Rohde was chairman. It was well thought out. At our Division meeting we spent considerable time discussing it and finally accepted it as now submitted.

Earle Buckingham:—Are the threads at the base of the spark-plugs the same as specified in the former standard or have the tolerances been changed to agree with the National Screw Thread Commission tolerances for that size?

O. C. Rohde:—After the meeting of the Electrical Equipment Division there was received a report on thread tolerance from the Screw-Threads Division, which was approved by letter-ballot, but is being held pending final settlement by the National Screw Thread Commission, and a Sectional Committee, sponsored by the Society and the American Society of Mechanical Engineers, which is reviewing the Commission's report.

Charles M. Manly:—What is the relative amount of production in this Country of the two-piece spark-plugs of the 7/8-in. size thread, for which I understand this enlargement is principally needed? It seems to me that this is a very important matter because of the question of there being so many spark-plugs standards requiring as many different sizes of wrench. This is one of the matters that has been taken up by Secretary Hoover's Division of Simplified Practice to reduce waste. This proposed change, if made, may result in simply adding another size, because I question very seriously whether the people who make spark-plugs of the one-piece type will really change over. There are thousands of users already equipped with spark-plug wrenches that fit the 7/8-in. hex. If we make this change we will have to answer to the public.

Mr. Rohde:—We have gone into this matter very carefully. Ever since the 7/8-in. hex standard was adopted by the Society the production of the two-piece plug, which requires a larger hex-size, has been about 60 per cent of the total production. That means that the 7/8-in. hex has never really become the general standard.

The present inside dimensions of both the two-piece and the one-piece spark-plugs have been used for the last 10 years. A change from a 15/16-in. to a 7/8-in. hex is impossible in the two-piece construction with the established inside dimensions for the gasket and porcelain. On the other hand, a change from a 15/16-in. to a 7/8-in. hex in the one-piece plugs requires only a resetting of the milling cutters. Both types are made from the same size stock, which measures 1 1/8 in. on the outside. The difference in the actual clearance with the two hex-sizes amounts to about 1/16 in. on the diameter across the corners.

Some argument has been advanced that we need a smaller hex-size because of the decreased clearances between the cylinders of some engines. When we come to that we will need a new-size plug with a hex and a thread-size smaller than the present standard. We are limited now by the outside diameter of the gasket, which was standardized at 1 1/8 in. for the 7/8-in. thread. In fairness to the two-piece spark-plug manufacturers we should change this standard. There are two points to be considered in this connection; efficiency as affecting interchangeability and fairness to the majority of the trade. I believe that the 15/16-in. hex in all types of plug will make a better, more efficient plug because it is less susceptible to wrench-strain, and it will make it possible for the two-piece spark-plug manufacturers to make an S.A.E. Standard plug without having to revolutionize their business.

Mr. Manly:—Figuring on the basis that, of 5,000,000

or more cars, 40 per cent are at present using the 7/8-in. standard, something like 2,000,000 wrenches would be immediately junked if the hex is changed. I hold no brief for the manufacturers of either the one-piece or the two-piece plug, but I am interested in the effect on the users who exist to the extent of some 2,000,000 at least, and are equipped with the 7/8-in. wrenches. I do not like to see the Society complicate the situation by adding to the so-called waste. I happen to be on a committee that was appointed to cooperate with Secretary Hoover in his prevention-of-waste program. It does not put us in a good position to have to go before this committee and say that we have scrapped 2,000,000 wrenches.

MR. ROHDE:—The one-piece spark-plug makers produce a large volume of plugs with 15/16-in. hex because there is a big demand for them. The one-piece plug with the 7/8-in. hex is required on very few cars. There is only one car that makes it necessary to use the 7/8-in. hex. There are a few cars with close clearances, on which a 15/16-in. hex plug can be used without any particular trouble. I do not believe we are going wrong in this change because we are decidedly doing something that will benefit the majority.

MR. ANDREW:—Seven-eighth-in. two-piece plugs are being made. They probably constitute 20 per cent of the production of that type of plug. I believe that Marmon, Overland, Oldsmobile and probably some others are using it. Their tappet-rods are so close together that they claim they cannot use a wrench that will take the 15/16-in. plugs.

I feel that the trend of development of two-piece plugs is toward the 15/16 in. If we are to set a standard at all, it ought to be 15/16 rather than 7/8 in. Sooner or later we will have to set a new standard for a smaller plug in all dimensions.

A. D. T. LIBBY:—I believe that those who are now making 7/8-in. plugs will still continue to make them, and that nothing we can do in the way of standardization will ever change the trend so far as the manufacture of the 7/8-in. plug is concerned. There is a demand for the 15/16-in. plugs and a satisfactory two-piece plug cannot be made with a 7/8-in. hex. That has been well considered and set forth in THE JOURNAL. Getting a well-made two-piece plug of the smallest dimensions possible, resolves itself into establishing the 15/16-in. hex standard.

I do not see that the question of wrenches enters into materially. We have 7/8-in. plugs in use and wrenches have been provided. The manufacturers who make 7/8-in. plugs will continue to furnish the wrenches with those plugs and those who make the 15/16-in. hex plug will furnish wrenches, but gradually more and more of the 15/16-in. plugs will be made.

MR. MANLY:—If this were a new proposition and we were trying to decide whether to make the plugs 7/8 or 15/16 in., I would be thoroughly in favor of the point of view that has been expressed. The Society has had a standard for a number of years. Now we propose to substitute the 15/16-in. standard for it, throwing all the former product into the scrap-heap, wrenches and all.

In view of the statement that sometime in the future there may have to be still another and smaller standard plug, it seems to me that a wiser move would be for the Society to have two standards, one for 7/8 and the other for 15/16-in. plug.

MR. ROHDE:—For years we have had two standard spark-plug sizes, 7/8 and 1 1/8 in. Then we adopted the metric size. In spite of the fact that those three sizes have been standardized, 60 per cent of all the plugs made during that time have been 15/16-in. hex, which was not standardized. Shall we continue a standard just because, as a matter of sentiment, we feel we ought to, or shall we specify the one that meets the majority of requirements and is really wanted by the trade? We will have two sizes, the 15/16 and 1 1/8 in. The question of a still smaller standard plug is entirely a matter of the future. Spark-plug manufacturers do not want it because it limits their working clearances. The car and engine designers may drive us to it eventually. We can wait until they do. We hope that they never will.

ENGINE DIVISION REPORT

FLYWHEEL HOUSINGS

(*December issue of* THE JOURNAL, *p.* 538)

THE DISCUSSION

J. B. FISHER:—There has been a demand for some time for something in the standard for flywheel housing limiting the space for the flywheel bolts and nuts. It was proposed last year that a clearance space 6 1/4 in. in diameter and 5/8 in. deep be provided. This was later changed to 6 1/2 in. in diameter, but was referred back to the Division because it was too limiting on the clutch design. Joint consideration by the Engine and the Transmission Divisions resulted in the recommendation now presented, which makes no reference to the diameter and therefore does not limit the clutch design.

IRON AND STEEL DIVISION REPORT

IRON AND STEEL SPECIFICATIONS

(*December issue of* THE JOURNAL, *p.* 539)

THE DISCUSSION

F. P. GILLIGAN:—The report of the Iron and Steel Division is more or less confirmatory of editorial revisions that seemed desirable. From time to time requests are received to recognize compositions varying slightly from the S.A.E. Standard compositions. In view of the fact that our standard compositions cover a majority of automotive requirements, the Division felt that it would be best to amplify the S.A.E. Standard for Iron and Steel Specifications by the inclusion of the proposed sentence in the first paragraph of Part I, p. D1 of the S.A.E. HANDBOOK.

With regard to the second proposal, all the other steels in the 3100 group have a sulphur limit of 0.045 per cent and this report is simply to confirm a sulphur limit of 0.045 per cent for steel No. 3115, instead of 0.040 per cent.

LIGHTING DIVISION REPORT

ELECTRIC INCANDESCENT LAMPS

(*December issue of* THE JOURNAL, *p.* 539)

THE DISCUSSION

HUGH M. PIERCE:—Has there been any recommendation with reference to the marking of incandescent lamps to indicate their rated candlepower?

W. A. MCKAY:—It is standard manufacturing practice to have lamps marked as to their candlepower.

TAIL-LAMP AND REGISTRATION NUMBER-PLATE ILLUMINATION

(*Proposed S.A.E. Recommended Practice*)

At a joint meeting held last June of members of the Illuminating Engineering Society's Committee on Motor Vehicle Lighting, and the Lighting Division of the Society of Automotive Engineers, a representative of the State of Massachusetts asked the two Societies to prepare standard rear registration number-plate illumina-

tion specifications for motor vehicles. A joint subcommittee was thereupon appointed which studied this matter carefully and gathered necessary information. The subcommittee held a meeting in New York City on Dec. 28 at which the subject and the accumulated information were reviewed and the proposed specification drafted for tail-lamp illumination of registration plates and recommendations made regarding the design of registration plates. These were considered at a joint meeting of the Motor Vehicle Lighting Committee of the Illuminating Engineering Society and the Lighting Division on the day following and revised somewhat. In view of the fact that the legislatures of most States will convene within the next 60 or 90 days and probably consider or enact legislation controlling tail-lamp illumination, it was the sense of the joint meeting that the proposed specification should be officially approved by the two Societies without delay.

Immediately following the joint session, the Lighting Division held a meeting at which the action of the subcommittee and of the joint meeting of the Committees of the two Societies was approved and it was unanimously voted to recommend the following for adoption as S.A.E. Recommended Practice.

TAIL-LAMP AND REGISTRATION NUMBER-PLATE ILLUMINATION

Introduction.—These specifications are intended to apply only to the illumination, by electric lamps, of opaque registration number-plates for use on automobiles, trucks, tractors and motorcycles.

Tail-Lamp.—A lighting unit used to indicate the rear end of a vehicle by a ruby light and to illuminate the registration number-plate.

Wherever reference is made in these Specifications to the registration number-plate it designates a rectangle 16 in. long and 6½ in. wide designed to bear the registration numbers, and located 1/16 in. in front of the plane of the front face of the plate-holder.

General Construction.—The opening in the lamp through which the light passes to the registration number-plate shall be covered with colorless glass and shall be sufficiently large so that the light will cover the entire surface of the plate.

The lamp and the plate-holder shall bear such relation to each other that the major portion of the light incident at any point on the registration number-plate shall make an angle of not less than eight deg. with the plane of the plate.

The lamp shall be weatherproof and dustproof and so constructed as to withstand the shocks and vibration to which it is ordinarily subjected in use.

Laboratory Test

Samples for Test.—The samples submitted shall be representative of the lamp as manufactured and as marketed, and shall include the bracket to which the registration number-plate is to be attached.

Marks of Identification.—Each lamp submitted must bear a distinctive designation prominently and permanently indicating the name or type of the lamp.

If the registration number-plate holder is detachable from the lamp, it shall bear the same distinctive name or mark as the lamp.

Incandescent Lamps.—Incandescent lamps used in connection with the laboratory test shall be of 2 cp., 6 to 8-volt rating, and of standard manufacture for automotive service. They shall be operated at 2 mean spherical cp. during the test. In the case of tail-lamps involving the use of special incandescent lamps, such incandescent lamps shall be submitted together with any necessary accessories.

Illumination Test.—The lamp and registration number-plate holder which is included with the sample submitted shall be tested, using an incandescent lamp as provided above. The apparent illumination as measured on white blotting paper shall not be less than 0.5 foot-candle at any point on the registration number-plate. The ratio of maximum to minimum illumination shall not exceed 30.

Requirements for Acceptance.—No lamp shall be considered acceptable unless it conforms with the requirements for measured illumination and the ruby light is visible for a distance of at least 500 ft.

No lamp shall be considered acceptable that is found unsatisfactory for any of the following reasons: unstable or bad mechanical construction; unduly dark or bright areas or excessive contrast in the illumination on the registration number-plate; cut-off of illumination within 1½ in. of the plate measured perpendicularly to the plane of the plate at the edge farthest from the light source.

Proposed General Information

It was felt that inasmuch as the character of the registration plates is an important factor affecting the illumination specifications, the following should accompany the proposed specifications as General Information:

WHEREAS, the laws of the various States require that the rear registration-plates of motor vehicles be illuminated so that they are legible at a distance of approximately 60 ft., and

WHEREAS, it is impossible to accomplish the proper illumination of the registration plates with the present lighting equipment, and

WHEREAS, the various motor-car builders and the manufacturers of lighting equipment need a definite standardization of registration plates to comply with these laws, and

WHEREAS, the color combinations, size of plate, size of stroke and spacing are of vital importance, therefore be it

Resolved, it is the sense of this joint meeting of the Lighting Committee of the Illuminating Engineering Society and the Society of Automotive Engineers that no specification for lighting the registration plate can be practically applied unless there is a reasonable standardization of registration plates as regards

(1) Maximum dimensions of the area to be illuminated
(2) Design and spacing for digits
(3) Color contrast

The joint committees further suggest that such standardization might be approximately as follows:

(1) The area to be illuminated to be included in a rectangle not larger than 6½ x 16 in.
(2) The design and spacing of digits to be such that
  (*a*) The stroke will not be wider than ½ in.
  (*b*) The spacing between strokes not less than ½ in.
  (*c*) A space of not less than ¾ in. will be provided between each third digit
  (*d*) The opening in such figures as 3, 6, 9 and 5 will be kept wide so as to avoid confusion between them or with the figure 8
  (*e*) The colors will be so selected as to secure high contrast between the numerals and the background

It was also the sense of the joint meeting of the two Committees that the proposal should be submitted to the Motor Vehicle Conference Committee and that that Committee should give the proposal wide publicity and urge the Conference of Motor Vehicle Administrators

to give it its support towards adoption by all the States of uniform legislation.

It was furthermore the sense of the joint meeting that the Society of Automotive Engineers should be requested to continue work on the formulation of standard registration number-plate and bracket-mounting dimensions and mechanical-strength specifications.

LUBRICANTS DIVISION REPORT

Crankcase Lubricating Oils

This report, which was printed on p. 540 of the December issue of THE JOURNAL, was revised by omitting the Explanatory Grade-Names, which were referred back to the Division; adding "Cleveland Open Cup" to Flash-Points; "Tests shall conform to the methods of the American Society for Testing Materials; and changing "Average Saybolt Viscosity" to read "Average Viscosity, Saybolt Universal."

THE DISCUSSION

K. G. MACKENZIE:—Certain changes in the specifications that were made last November were not important so far as the specifications were concerned, and involved chiefly, I believe, extending the color scale so that color determinations might be made on all grades of oil. However, radical changes were made in the explanatory grade-names. For instance, Specification No. 40, which at the September meeting of the Division was agreed upon as Heavy, became Medium; Specification No. 50, which was Extra Heavy, became Heavy; and, most serious of all, Specification No. 60, which was Extra, Extra Heavy, became Heavy.

The first problem in automotive lubrication was the selection of proper lubricants. A number of the larger companies have grades that have been advertised and sold for a long time as light, medium and heavy. The new grading would seriously change this practice. It seems to me that what the Society desires is first that the oil companies recommend oils according to certain S.A.E. Specification Numbers and then that the petroleum refiners state in their advertising and on their cans that their trade-names and grades correspond to certain S.A.E. numbers. Of course, there is a difference of opinion as to what are light, medium or heavy oils, but it would be a serious thing for the Society to state definitely that a given oil is light, medium or heavy, if the statement did not agree with the majority of trade practices.

As a member of the Lubricants Division, I feel that not enough work has been done by the Society to determine what oils should be classified as light, medium, heavy or extra heavy. It is important to include some sort of explanatory grade-names in the specifications, but it is unfair to ask the manufacturers to make changes to conform to the grades that we may select today.

I would like to recommend action that would not meet the situation entirely but I think improve it by changing No. 40 from medium to heavy, and No. 60 from heavy to extra heavy, to bring the explanatory grade-names more into line with the present grading practice and provide for two light, two medium, two heavy, and four extra-heavy oils.

MR. MANLY:—It seems to me that this report should be adopted as S.A.E. Recommended Practice and its provisions tried out for a reasonable length of time before adopting it as S.A.E. Standard. I therefore move that it be approved for adoption as S.A.E. Recommended Practice. [The motion was seconded.]

J. W. STACK:—No standards have been established in the oil business as to what constitutes a medium, a heavy or an extra-heavy oil. One refiner's heavy oil may be another's medium grade. However, in the Mountain and the Central Western States heavy oils of the most popular brands today have over 500-sec. viscosity at 100 deg., which would bring them into the 60 class at 210 deg. The extra-heavy oils, including those for motorcycles and tractors, have about 100-sec. viscosity at 210 deg. For many years we have been marketing extra-heavy oils of about 100-sec. viscosity at 210 deg. and I think that an oil of 60-sec. viscosity at 210 deg. should not be known as an extra-heavy oil.

H. C. MOUGEY:—For a long time the Division did not recommend the use of explanatory grade-names, but there seemed to be an insistent demand that some sort of descriptive names be coupled-up with the specification numbers since so many people are in the habit of referring to oils only as light, medium, heavy and extra-heavy. We found that it was impossible to assign a definite name, such as light, medium or heavy, to a definite specification, and the groups into which we classified the several oils, light, medium, heavy and extra-heavy, were the best compromise we could make inasmuch as the oil industry itself had not standardized on the viscosities of oils that are sold under the different classes.

MR. MACKENZIE:—In regard to Mr. Stack's remarks, I would say that the Texas Co. has marketed to its entire satisfaction an extra-heavy oil that corresponds to the proposed S.A.E. No. 60. Of course, this is a naphthene-base oil. I think that the general classification followed by the Texas Co. is followed almost unanimously by those firms which market naphthene-base oils.

I would like to offer an amendment to the motion, changing the explanatory grade-name of No. 40 from Medium to Heavy, and of No. 60 from Heavy to Extra Heavy, because I think some of the companies would like to tell the public now to just which of the S.A.E. Specifications they will conform. (This motion was seconded.)

CHAIRMAN E. A. JOHNSTON:—Is that amendment acceptable to you, Mr. Manly?

MR. MANLY:—I confess that I do not know very much about oils technically but, to bring the matter to an issue, I accept the amendment. [The amendment was accepted by the seconder of the original motion.]

H. S. PIERCE:—If some confusion will be brought about by changing the names now being used, why not simply use grade numbers?

MR. MOUGEY:—That was the intention of the Lubricants Division for some time, because the oil industry is not agreed on names that correspond to the different viscosities; but, as there was such a demand that names of a more or less descriptive nature be included in the specifications, this system was presented as a way of meeting this requirement without upsetting the commercial practices that differ among companies.

W. H. HERSCHEL:—There are two conflicting points of view that the Division has endeavored to reconcile. One is that of the refiners who have certain brands of oil on the market which they do not want to change. The other is that we want to help the purchasing agents who are accustomed to buying oils by certain names and designations of light, medium and heavy. We wish to avoid definitely naming specific classes of oils, so as not to limit the refiners. But to omit entirely any descriptive names would leave purchasing agents, who are unfamiliar with classification by viscosities, entirely at a loss when buying different grades of oil.

I believe that the strictness with which these specifications are intended to tie a certain explanatory trade-name to an oil of a certain viscosity has been over-

emphasized. The explanatory grade-names in reference to specific oils are merely given as a guide to purchasing agents as to approximately which grade of oil they may expect to be satisfactory for their particular use. If it is felt that the report implies that a definite specification-number should go with a definite explanatory grade-name, the grade names might be omitted and a statement made that in general such and such specification-numbers correspond approximately to such and such an explanatory name.

MR. STACK:—I believe the point that we have been discussing is relatively an oil-man's marketing problem and really not an engineering one. The report should be adopted as it stands inasmuch as the nomenclature was approved by the Division after a thorough survey of existing oils on the market.

MR. MACKENZIE:—At the conference in the City of Washington on Nov. 13 the matter was referred to a Committee of three, one representing the American Petroleum Institute, one the Society of Automotive Engineers and one the Inter-Departmental Specifications Committee. A majority report and a minority report were made on behalf of this Committee. The majority report, made by the two first-named members, approved the proposed grade-names; the minority report practically approved the old classifications.

MR. HERSCHEL:—As I recollect the matter, the minority report was in favor of using a different standard of tests for oils and did not really have a bearing in this connection, because it did not consider any system of names for the particular specification-numbers given in the Division report.

H. L. POPE:—What we need most is definitions as to what these grade-names mean. I do not see how it will be possible to satisfy all concerned until those definitions are agreed upon. I would like to suggest that the grade-names be eliminated from the report and referred back to the Division to prepare definitions for them.

CHAIRMAN JOHNSTON:—The motion before you is to approve for adoption as S.A.E. Recommended Practice the report as submitted, leaving out the descriptive names and including references to the Open Cup and the American Society for Testing Materials methods of testing.

[The motion was carried.]

NOMENCLATURE DIVISION REPORT

AUTOMOBILE NOMENCLATURE

(*December issue of* THE JOURNAL, *p.* 541)

THE DISCUSSION

MR. POPE:—To make much headway in its work the Nomenclature Division requires considerable time on account of the large scope and vast amount of detail involved. The main accomplishment during 1922 was to lay down a plan that, if properly carried out, will eventually give us a pretty complete nomenclature, covering all branches of the automotive industries. After the plan had been determined, an organization was gotten together which in the main has been gathering data that should result in some fairly complete recommendations during 1923. The subdivisions appointed are working on nomenclatures for Aeronautics, Highway Transport, Power Farming, Motor Transport, Motorcycles, Stationary Engine Operation and Industrial Service.

The Nomenclature Division report at this time recommends that the present Differential Nomenclature, included in Division 12, Group 4, of the present S.A.E. Standard for Automobile Nomenclature, be revised as outlined by the Subdivision and approved by the Gear Manufacturers' Association.

PARTS AND FITTINGS DIVISION REPORT

PLAIN WASHERS

(*December issue of* THE JOURNAL, *p.* 541)

THE DISCUSSION

MR. ANDREW:—In looking over the tolerance allowed on the thicknesses, it seems to me that ±0.010 in. is pretty liberal on a washer 1/32 in. thick.

F. G. WHITTINGTON:—We did not think that tolerance could do any harm, and certainly it would be less restrictive.

MR. ANDREW:—What material may these washers be made of?

MR. WHITTINGTON:—Usually of scrap stock, or stock that is not held very close to nominal thickness.

STORAGE BATTERY DIVISION REPORT

RATING OF STORAGE-BATTERIES FOR ISOLATED ELECTRIC-LIGHTING PLANTS

At the Standards Committee Meeting the Division presented a revised report in place of that printed on p. 545 of the December issue of THE JOURNAL. The revised report is printed below in full.

RATING OF STORAGE-BATTERIES FOR ISOLATED ELECTRIC-LIGHTING PLANTS

(1) Lead-acid storage-batteries for isolated electric lighting-plant service shall have two ratings, a continuous rating and an intermittent rating. The ratings shall be determined at an initial electrolyte-temperature of 80 deg. fahr. and be based on a final voltage of not less than 1.75 volts per cell.

(2) *Continuous Rating.*—The continuous rating shall be the capacity in ampere-hours of the battery when it is discharged continuously at the 8-hr. rate.

(3) *Intermittent Rating.*—The intermittent rating shall be the capacity in ampere-hours of the battery when it is discharged intermittently over a period of 72 hr. The standard test to determine this capacity shall be as follows:

> Discharge at a current rate equal to 1/24 of the intermittent ampere-hour rating of the battery for an initial period of 4 hr., followed by a 16-hr. rest; then discharge at the same rate for two 8-hr. periods, each followed by a 16-hr. rest, and for a final discharge period of 4 hr.
>
> The rest periods are arranged so as to avoid night work when the test is begun at noon.

(4) Except for the final voltage per cell, the ratings apply to nickel-iron batteries as well as to lead-acid batteries.

(5) Both ratings should be cataloged in the following form:

> S.A.E. Ampere-Hour Capacity Rating: 100-140: The first number represents the capacity based on the continuous rating and the second number the capacity based on the intermittent rating.

THE DISCUSSION

W. E. HOLLAND:—The rating of storage-batteries for isolated electric-lighting plants has been under animated discussion for the last 4 years. After a number of meetings of the Isolated Electric-Lighting Plant Division, the Society adopted a 72-hr. intermittent rating but, as this did not prove satisfactory to the Farm Lighting-Plant group of the National Gas Engine Association or to a large number of the manufacturers, the Division of the Standards Committee attempted to standardize an 8-hr.

continuous method of rating. This also met with considerable opposition and the work came to a deadlock. There seemed to be no way out until the subject was recently reassigned by the Council to the Storage-Battery Division, and we decided that the only standard that could be recommended at this time is a double standard. This was done, after very careful consideration of the history of the work, by unanimous vote of the members of the Division.

As there was a slight objection to some of the wording of its recent report, the Division met this morning and came to a decision as to how the final recommendation should read.

Storage-Battery Monobloc Containers

This recommendation, which was printed on p. 545 of the December issue of THE JOURNAL, was revised by changing the last line under "Height from Top of Ribs to Top of Container" to read "Maximum variation of different compartments of the same container, 1/32 in."

TRANSMISSION DIVISION REPORT

Clutch Facings

The caption under the cut on p. 546 of the December issue of THE JOURNAL should read "Proposed Dimensions for Clutch-Facing and Rivet Holes," and the fifth line of the indented paragraph in the second column should read "the rivet-hole sizes" instead of "the rivet sizes."

TRUCK DIVISION REPORT

Before presenting the recommendations of the Division for consideration by the meeting, F. A. Whitten, chairman of the Division, reviewed briefly what had been accomplished in the past 6 months. He said among other things

> The Truck Division this year has endeavored to follow the practice of last year's Division, which seemed very commendable, by concentrating on the things that we thought could be done. We carefully studied all the subjects that were referred to us, and by a process of elimination finally decided to disregard certain subjects because they were not important, or it did not seem possible to formulate standards for them at the time.
>
> There are only two important subjects in progress, I believe, before the Division. The first is power takeoff shaft-ends, which is in the hands of a Subdivision for circularization and a report.
>
> The other very important subject which is still before the Division is that of motor-truck ratings, so-called. The name is rather indefinite. The subject was assigned as a special one to the Division because there seemed to be no doubt that in the licensing of trucks to operate, the Motor Vehicle Commissioners of the various States would be guided, to an extent that they never had been guided before, by the detailed construction and the safety of the trucks in operation. There are various reasons for this, some pertaining to highways and others to the safety of other vehicles on the highways. A number of suggestions were made as to the nature of possible recommendation and the matter referred to a Subdivision that has worked with the National Automobile Chamber of Commerce and other organizations interested in the subject. This was advisable because there are considerations more vital in some ways to the manufacturers than the engineering ones.
>
> It seemed at one time that the matter involved finding some way of regulating and registering the capacity of trucks and the strength of certain elements, such as axles, steering-gears and brakes, but procedure in this direction did not prove very practical. The subject is a large one and we can only report progress at this time.
>
> As a result of concentration on a few subjects the Division has made only three recommendations.

Vertical Dumping-Hoist Platforms

(*December issue of* THE JOURNAL, *p.* 546)

THE DISCUSSION

F. A. WHITTEN:—The first of our recommendations is on vertical dumping-hoist platforms; that is, the substructure on which vertical hoists of the hydraulic, screw-operated and plunger types are mounted on the chassis frame. This subject was taken up because various companies, in mounting the hoists, drill all sorts of holes in the frame, which results in weakening and sometimes the failure of this member.

It was originally intended to recommend certain standard dimensions, but this was not feasible because of the possibly necessary variation between designs.

Body Hold-Down Clamps

(*December issue of* THE JOURNAL, *p.* 547)

THE DISCUSSION

MR. WHITTEN:—In connection with the subject of Body Hold-Down Clamps, there has been a demand from various sources for improved methods of mounting bodies on chassis. Bodies, in the majority of cases, are not supplied by the truck builders and all sorts of means have been used for fastening them down. This has caused all of us more or less trouble.

UNACCEPTED RECOMMENDATION

BALL AND ROLLER BEARINGS DIVISION

Metric-Type Thrust Ball-Bearings

(*December issue of* THE JOURNAL, *p.* 531)

THE DISCUSSION

F. W. GURNEY:—There has been considerable discussion regarding this matter of metric bearing-sizes. We all know that there is great opposition throughout the Country to the general adoption of the metric system that has been dragged into this matter. I hope there will be a general expression of opinion and a clearing-up of misunderstanding on the subject at this time and I will ask H. E. Brunner to make the report for the Subdivision, as D. F. Chambers, who is its chairman, is not present.

H. E. BRUNNER:—Approximately a year ago, the Ball and Roller Bearings Division appointed a Subdivision to undertake the standardization of metric-type thrust ball-bearings by bringing the various manufacturers into agreement on definite sizes of bearings. This necessarily involved making concessions, and in this manner the dimensions of the thrust bearings as given in the report were selected.

The problem was one of getting the exterior dimensions agreed upon, the bores being practically standard at the time. While this is a proposed new standard, it is not necessarily a new series of bearings nor a new group of bearings. It antedates the so-called inch-dimension standard of today and, so far as the metric phase of the situation is concerned, I do not see why it should necessarily stand in the way of the adoption of a standard for a class of bearings that has been so generally used. This standard would make it better for the manufacturers by eliminating the difference existing in bearings of corresponding sizes.

J. T. R. BELL:—It seems to me that in view of the

opposition the matter should be postponed. There are many arguments for and against, and the subject ought to be threshed out more thoroughly.

MR. ANDREW:—Are not the bearings of this type we are now using predominatingly in metric sizes?

MR. BRUNNER:—Yes.

MR. ANDREW:—My company uses both metric and inch-size bearings. We find no difficulty whatever in putting inch-size balls into metric-size bearings. I think the matter should be carried at this time in favor of the metric bearings as they are already a standard in our Handbook insofar as the ranges of sizes and tolerances are concerned.

MR. MANLY:—In the consideration of this thrust-bearing proposition before the Division, the most important point was that we could not get, apparently, any real information on what is the general attitude of the American manufacturer toward the metric sizes. Those of us who have spent considerable time on this subject certainly urge that those here today speak freely on this whole question so we can get some idea of what the general attitude of the automotive industry is. We are bound to have metric thrust-bearings in aeronautical work and it will be very important to have the bearings interchangeable, but that will represent a small portion of the total automotive use of thrust bearings at least for the next few years and I think it is not important from the point of view of the total automotive production.

R. G. CORNFORTH:—The view of our company on the matter is that of the thrust ball-bearings used, the inch sizes are by far in the majority.

It seems that it has been the practice of the Society to standardize in inch dimensions and to avoid, if possible, all metric dimensions; in fact, the standards for American automobiles are almost entirely in inches. It has been the practice in international work for the country that leads in the production of any article to take the lead in setting a standard. Surely, there is no question that the United States is far in the lead in the automotive and the machine-tool industries. From these standpoints alone, I think it is reasonable to think that it would be a step backward to standardize in metric dimensions.

There was some thought during the war that we needed standardization in inch dimensions due to the fact that in the construction of airplanes we were unable to obtain bearings of foreign manufacture which were in metric dimensions. This confused the matter, and we had to make our own bearings. We were building planes to meet the demand overseas, the parts being interchangeable with the parts used there. However, airplanes are practically a new proposition. Inasmuch as they will be developed extensively in the years to come, let us start this bearing standardization right, and in the inch system.

MR. GURNEY:—Referring to one point that Mr. Cornforth brought out, there is no intent to supersede the present inch standard[1] that has existed for several years. The standard that is now proposed is one that is naturally based upon the old millimeter standard and has equivalents in inch dimensions. It might be mentioned that converting millimeters to inches gives figures in decimals that naturally have to be used in the production of anti-friction bearings. This proposed standard goes hand-in-hand with what may sooner or later be an international standard because at the present time considerable work is going on in that direction.

[1] See S. A. E. HANDBOOK, pp. C35 to C39.

MR. MANLY:—This matter is of much more importance than the mere discussion of the thrust bearings themselves. For more than 2 years a joint committee sponsored by the American Society of Mechanical Engineers and this Society has been working on this proposition in connection with the Swedish and German committees. O. Wikander, a member of this committee, is now in Europe getting further data.

I accepted membership on this committee largely to see whether or not there is any possibility of international standardization. If we can not agree on international standards in connection with ball bearings, there is no possibility of international cooperation in the matter of standardization. If it were a proposal in connection with threads or gears I feel it would be absolutely hopeless, because there are measurements involved that cannot be converted; there can be no interchangeability of either gears or screw threads.

As to ball bearings, we have the annular series, which are so extensively used that I imagine no one would favor such a handicap on industry as the abandonment of their metric sizes. This matter of thrust bearings brings up the question whether we shall have two standards, an English and a metric, for thrust bearings, so that there can be some guide toward eventual international standardization, or the Society shall take the lead in being absolutely opposed to any attempt to bring about international standardization of products?

This is a very big and important matter and should not be simply thrown back into the Committee's hands. We have been trying to ascertain the sentiment of the American industries on it, and do not want it settled merely on the basis of an international exchange-rate or by a League of Nations. We should have a free expression of opinion as to whether the Society is ready today to say that this one recommendation, which is the most likely of any I know of to be carried through as a matter of international standardization, shall be adopted, or we shall reject it and say that henceforth it will be of no use to talk about international standardization.

PRESIDENT B. B. BACHMAN:—I can readily understand that there is some demand for the metric-size thrust-bearing, for the reason that in automotive apparatus, and possibly other apparatus, it is used in conjunction with metric-size annular-bearings. Naturally, measuring instruments and tools can be interchanged readily if the dimensions are similar. On the other hand, there has arisen a large usage of the inch-size bearings, probably in connection with plain bearings and plain journals and that in this connection the inch sizes would be most logical.

We always have a difficult problem when a large body of experienced men attempts to divert by arbitrary action the course that experience has pointed out. We have among our present standards illustrations of attempts to create standards that in themselves were logical and defensible, but that, through commercial restriction, have never come into usage. This is a phase of the problem that we should consider very seriously.

The minority report printed on p. 535 of the December issue of THE JOURNAL relates in large part to the division of opinion regarding inch and metric dimensions, but it contains also the statement that some of the sizes presented can be criticized from a design standpoint. In my estimation that is considerably more serious than whether the bearings are in metric or inch dimensions.

As a matter of the Society's procedure, this is one of the cases in which complete discussion in Standards

Committee meetings is advisable. Whatever the outcome of our discussion may be, I thoroughly believe that where a logical division of opinion exists among competent minds on a subject of this character, action should be delayed until an agreement can be reached, irrespective of the merits of the two sides of the case.

Finally, I do not believe we will ever have adequate standards action by a majority vote; it should be by practically unanimous consent.

MR. POPE:—There is no question but we should try to use the inch measurements in all our work, but those who expect to get foreign business under present circumstances, in some cases at least, must compete with the foreign dimensions. If we want to sell in South America, for instance, or if any foreign country goes into South America with its goods, it must use the metric system unless there is sufficient merit in the article made to inches to compete with the metric article made in foreign countries.

We are building the Wright Hispano engine, which resulted from our building the French engines for the French Government, and have been using metric measurements. We are, however, designing our new engines in inch measurements, including the ball-bearings. But we might get a sufficient order from some foreign country to make it advisable to continue to build interchangeably with the French Hispano, the English Hispano and the Spanish Hispano. I can conceive of a ball-bearing manufacturer in this Country becoming so efficient in the production of ball bearings that he could compete with a foreign manufacturer, but in so doing he would have to supply the ball bearings that the foreign market wants. Unless we can convince such a market that the inch is the right standard, it will want the metric standard.

Can we not state in our standards that it is desirable and recommended that, so far as possible, American manufacturers design their product to English measurements for ball bearings, but that wherever a manufacturer is forced to make metric ball-bearings he should follow the metric standard?

EARLE BUCKINGHAM:—As I understand it, these metric thrust-bearings have the same bores and outside diameters as the metric radial bearings that we already have. I see no reason why the question of metric versus inch measurements should enter at all. I think there are not many here who would care to see the inch system of measurement abandoned entirely in favor of the metric. Neither do I see how the adoption of a series of thrust bearings like this would lead us in any way to that step. If we have a series of radial bearings and we wish to use thrust bearings in conjunction with them, it is essential that we have the proper bearings to do so.

I understand that these metric bearings are not proposed to the exclusion of the present standard of inch-type bearings that was formulated by the Ball and Roller Bearings Division some years ago for use where the inch sizes are preferable. I think the question should be decided solely on its own merits; if there is sufficient demand for thrust bearings of these general dimensions, I see no reason why we should not adopt them.

MR. GURNEY:—It should be understood that it is not the function of the Standards Committee to create new standards that it can force on the industry. What we ought to arrive at today is the facts as to what bearings of this type are at present being used or will be used.

There has been in existence for years a series of thrust bearings in inch sizes. This new line that the Subdivision has worked out is merely to recognize standards that are already in existence and use. That is all the Standards Committee can do, practically, anyway. We cannot reach up into the air and draw out standards that we can compel the industry to use.

It should be borne in mind that all the bearings originally laid out in the metric sizes, such as the annular bearing sizes, are being used and applied practically universally throughout the industry in inch dimensions.

I do not know of a single company in this Country that deals with these dimensions in metric terms, as the limits and tolerances are universally expressed in inch dimensions, usually in decimals carried out to the fourth place. The common limit of measurement throughout the industry is what we usually call the tenth, meaning 0.0001 in.

It is unfortunate for us that the original annular sizes that were established in Germany nearly 20 years ago were metric sizes. It would be fine if all of this could be wiped out and we could start anew with the knowledge and experience we now have. We could avoid considerable trouble.

The geometric progression of sizes is ideal and I wish it could be adopted, but this is practically impossible. It would mean the carrying along of two independent standards for a long time until one or the other should become obsolete. We know that the intervals between the sizes, the 5-mm. intervals on the bore and the 10-mm. intervals on the outside, are too great on the smaller sizes, but they are all right on the larger sizes. We very much wish that they might be changed to a geometric progression but none of us feels that we can afford to establish new sizes and double our whole equipment of jigs, fixtures, dies and gages.

MR. BELL:—I am not opposed to either one standard or the other. This matter, as it now stands, is a commercial one entirely. The five or six companies making ball bearings in metric sizes, who are the older and were until a few years ago the larger firms, are in the majority on the Standards Committee. One or two other companies are making by far the larger number of these thrust bearings which are used in steering-gears and clutches on practically every type of car; and so far as I can find out they are made in three to four times the number of the metric type.

This particular metric type of bearing has been in existence in these sizes from 16 to 20 years, the same length of time as the annular bearings, and is used by the majority of manufacturers.

MR. LIBBY:—I want to emphasize very strongly Mr. Bachman's thought that when we adopt standards we ought to have a practically unanimous vote. I have been on one of the Divisions for the last 6 or 7 years and I, too, have become convinced that that ought to be the rule.

It seems that there is a great difference of opinion on this thrust-bearing subject and that it ought to be referred back to the Division for further consideration and accumulation of data, with possibly consultation with the Aeronautic Division. I gather from the discussion that the percentage of these bearings in production is rather small. No great harm can be done by laying this matter over pending further development.

D. F. CHAMBERS:—As we all know, the metric system of bearings was inherited from Europe, particularly in the annular-bearing sizes. I do not know exactly where the demand came from for these metric-size thrust-

bearings, except that they have been made in this Country for about 15 years.

Our company must use both the inch and the metric systems on account of the demand. I was unable to gather very definitely in our 18 months' work just exactly what the requirements are in the number of sizes, or in quantity production, but certain sizes, mostly of the double-direction type, are in considerable demand.

With regard to whether the containers would have sufficient strength when using the larger diameters of ball with the proposed outside diameters of bearing, it has been agreed that the cage designs would be sufficiently strong. We used about 10 different companies' lists of bearings and from them worked up a compromise in sizes in the proposed standardization.

There was brought up at our meetings the matter of trying to standardize ball sizes. That is really impossible because the ball sizes, as well as the number of balls used, vary between makes and designs. Our only object in proposing the adoption of a standard is to establish the boundary or volumetric dimensions.

MR. MANLY:—This project did not grow out of the air. At least four companies have been listing metric-type thrust-bearings for many years. We had considerable trouble in getting thrust-bearings for our airplanes in 1915 and 1916 when the submarine campaign was shutting off importations pretty extensively. We had built a number of engines at Buffalo at the Curtiss plant that were designed to use S K F thrust-bearings. The submarines got some of the ships that were bringing the bearings over and our whole production was held up. We had to procure substitutes. We found that no two companies listing these metric-type thrust-bearings were working to the same dimensions. We, therefore, had to take some that were over-size and have them reground as the quickest way to meet the situation.

That impressed on me the importance of the American manufacturers and the American engineering societies cooperating with the Europeans in trying to bring some order out of the chaos that exists at the present time due to the lack of standardization for these thrust-bearings. We are not trying to force upon the American manufacturer the substitution of metric thrust-bearings for the inch thrust-bearings; nor do we recommend the use of one as opposed to the other.

There is, has been and no doubt will continue to be a certain demand for metric-type thrust-bearings. This report is simply an attempt to get those manufacturers in this Country who list metric-type thrust-bearings to do two things: to come together and adopt a standard to which they will all work, and to try to get such a standard lined-up with the work that is being done in Germany, Sweden and the other countries that are using the metric standard. When we do adopt some standard it should harmonize with the largest number of foreign standards and prevent at any time such trouble as has arisen before.

I am very sure that there will continue to be in aviation work a strong demand for the continuance of the metric-type thrust-bearings.

MR. CORNFORTH:—Let us not forget that we are leading in the building of automobiles; our product is widely used abroad in preference to foreign makes. When will the time be that American labor conditions will be such that we can meet competition with foreign labor? That is the chief thing that brings the cost of bearings up today. It seems to me that a metric standard would encourage importation and disrupt our market.

C. T. MYERS:—This Country not only produces from 80 to 90 per cent of the automobiles in the world but it will sell them all over the world. We are very much concerned not only in the building of these automobiles but in the servicing of them. Our products will have to meet competition abroad first as American cars, trucks and tractors, and then as individual machines.

It is of vast importance, considering the fact that the English dimensions are universally used in our own manufacturing, that we have first at least an English standard which will be in a proper ratio for various applications, because it is inconceivable that all the different automobile and truck companies will maintain service-stations throughout the world where they can service every part of their own cars. We must come down to the point where, by proper organization, a central warehouse can carry parts for practically all American cars.

I think that is the viewpoint we should bear in mind in this situation. We will have to fight for foreign trade. We ought to have standards that are our own, that conform with our own tool equipment, our own manufacturing methods. If the English-dimension series of thrust-bearing standards is not what it ought to be at present, the Division should undertake that piece of constructive work. If after that there is a demand for metric-size thrust-bearings in this Country, they should consider and submit such a standard because we should never again be in the position to which Mr. Manly referred of having to depend on a foreign manufacturer to furnish even the metric-size thrust-bearings that we may need.

MR. GURNEY:—It seems to me that this matter narrows right down to the question of whether the demand for these metric sizes is large enough and of sufficient importance for us to recognize it as a standard.

MR. PIERCE:—Mr. Manly spoke regarding the international standardization aspect of this case. I think that every time we attempt international standardization the problem of whether it shall be expressed in metric or inch dimensions will come up. If we accept and put on our records standards in the metric dimensions, it will in a way strengthen the other fellow's side of the case in the majority of instances. If we make and use our products almost exclusively in inch sizes and if we predominate in the production of any article, it seems to me the inch sizes should be used.

CHAIRMAN JOHNSTON:—This matter has been discussed thoroughly enough for us to make some decision. There is a motion before you, which has been seconded, that the proposed metric series of thrust bearings be adopted.

[A count of those voting in favor of and against the motion was taken]

CHAIRMAN JOHNSTON:—The motion is lost.

MR. MANLY:—I move that this matter be referred back to the Division that originally submitted it.

[The motion was seconded]

GEORGE R. BOTT:—The Ball and Roller Bearings Division has been functioning for about 8 years, and considerable has been done in the standarization of bearings. The standardization of inch-size thrust-bearings was accomplished after much work and the question of metric-size thrust-bearings has been before the Division for about 5 years.

After studying it we realized that there is very little objection to a metric standard for the reason that those who desire inch-size thrust-bearings can certainly obtain them, and if there is a demand for 1,000,000 or 2,000,000 bearings that demand should be filled. The standard-

ization of these metric-size thrust-bearings is not a question of whether we wish to use metric sizes or inch sizes, but a question of standardizing, making a fewer number of types or varieties of metric sizes. Of five makes of metric bearing, the sizes of which deviate possibly 1 or 2 mm., the bores are strikingly standard, and the outside diameters vary little. The differences are largely in the heights.

The effort in this work has been to standardize on a few sizes of metric thrust-bearing so that they will all be alike. That has its great advantages. It is not a question of placing the metric-size bearings before the manufacturers and demanding that they be used; it is a question of standardization by trying to eliminate large numbers of sizes.

It has been stated that the automobile industry desires inch-size thrust-bearings. That is true and it should be so. There are, however, demands for metric thrust-bearings, chiefly in the tool industry, and we are proceeding in the proper way if we standardize so that the user could get the same bearings from one or a half dozen different manufacturers. It is not a question of using the metric system; it is not a question of using the inch system. All designers have a right to use whatever they please. The machine-tool industry uses a great many metric size S. A. E. Standard radial annular-bearings, and metric thrust-bearings.

Speaking from the standards point of view, we desire the reduction of the large number of sizes so that the manufacturers who make metric thrust-bearings will have a minimum standard to work to for the future. Then the man who decides to use metric bearings for one reason or another will have a chance of getting a particular size from one or a half dozen sources.

To those who think that they will be handicapped by another standard of thrust-bearings, I want to say that it will not affect them. It will permit the Standards Committee to bring together the odd sizes, and to do its standardization work properly. It will enable each manufacturer of bearings to make the sizes that are in demand; it will enable the manufacturers of inch thrust-bearings to make as many as they care to make and, likewise, it will enable the manufacturers of metric thrust-bearings to standardize on one set of sizes so that they can supply their demand.

CHAIRMAN JOHNSTON:—Gentlemen, it has been moved and seconded that this subject be referred back to the Division.

[The motion was carried]

PROGRESS REPORTS

In addition to the various recommendations that were discussed and voted on at the meeting of the Standards Committee, two progress reports were presented. One of these reports, that of the Axle and Wheels Division on Differentials, with such discussion as followed its submission, is printed below. The other report on Motor-Truck Cabs that was presented by the Truck Division was printed on p. 547 of the December issue of THE JOURNAL. The remarks made by F. A. Whitten, chairman of the Division, in submitting the report are printed below.

AXLE AND WHEELS DIVISION

DIFFERENTIALS

For some time there has been a feeling that differentials should be standardized. This has resulted in the appointment of a Differential Subdivision of the Axle and Wheels Division of the Society, and a special differential standardization committee in the American Gear Manufacturers Association. The personnel of the two committees is, to a certain extent, over-lapping. This is fortunate as it avoids duplication of work, and insures harmony.

The first part of the differential standardization program embraces two sizes of differential, the inside parts of which have become automatically standardized to a very large extent, through their use over a period of years, by several of the most prominent manufacturers of differentials and axles.

The inside pinion and the bevel gear of the smaller size are an 10-18 tooth combination cut 5/7 pitch. The pinion, as well as substantially the tooth proportion, has been in general use in a wide variety of differentials for some years, so that the standardization of that much should not be difficult. Where the differences do occur, they are chiefly in the matter of the hubs of the gears, and variation in practice as to the method of supporting these gears in the case. Some manufacturers support the gear entirely in the differential spider, others support it entirely in the case, while still others endeavor to get a bearing in both places. In the form under consideration[2], the support is entirely in the spider.

The other size is a 11-20 combination, also of 5/7 pitch. This size likewise is already in very general use, and we should not find it very difficult to reach an agreement upon it.

The report includes the spider for the smaller size, and the corresponding spider for the larger size. These spiders are quite conventional. The bores are ground to provide a seat for the hubs of the side gears.

There are also included in tabular form the principal dimensions of the cases for both sizes of differential. On account of the wide variety of design in general use, it has been found very difficult to arrive at a harmonious and consistent set of dimensions for the case.

There should not be any great difficulty in arriving at a satisfactory conclusion as to the inside dimensions, since these would be made to agree with the corresponding dimensions of the inside parts already discussed.

For the outside dimensions it is necessary to take care of a great variety of practices as to the location of the flange by which the bevel gear is mounted, as well as varying hub-sizes, to accommodate different kinds and sizes of bearing.

In the case of the flange location it was found feasible to establish diameter standards, but no attempt has been made to locate the flange with reference to the center of the differential more than to show a maximum center-dimension. In the matter of hub dimensions, the various bearing manufacturers have been consulted, and average sizes arrived at which were in agreement with their recommendations.

It will be noted that both of these sizes of differential are of the four-pinion type. The two-pinion type of differential has been kept in mind in the course of this work, but it was not thought best to put anything out on that type before the four-pinion type shall have been first more thoroughly established. The two-pinion design would be based on substantially the same inside parts, although it will probably be necessary to modify the designs of the hubs on the side gears when used in two-pinion cases.

What the Subdivision now desires from the membership is a general expression of opinion as to its work thus far. Is it practicable for us to attempt at complete standardization as shown? Does this work meet with sufficient approval to warrant proceeding with other sizes, perhaps both larger and smaller, after these two sizes shall have been completed and adopted?

It is realized that this is a more complete dimensional standardization than is usual in S.A.E. Standards prac-

[2]The tentative recommendation of the Subdivision will be found on p. 124 of the January issue of THE JOURNAL.

tice, but it is the feeling of the Subdivision that it is worthwhile to have this, as a guide, to manufacturers and designers. It is not to be expected that in every case a designer would be able to accept the entire design from end to end. It is the thought, however, that the designer would use the dimensions indicated on the standard to just as great an extent as possible. In that way we would hope, gradually, to reduce the immense number of designs that are now in use, and for which there is no real reason, except that the designer in laying-out his work has no standard from which to start, and in many cases lays-out the proportions very largely to suit his own fancy.

The Subdivision hopes that all members interested in the report will take the designs as submitted which are given in full on p. 124 of the January issue of THE JOURNAL, and lay them out full-size on the drawing-board in their own axles, and from that base their criticisms and suggestions.

THE DISCUSSION

MR. BURNETT:—The object in bringing this report before the meeting is to get discussion on it. It relates to an important subject. We want to have the benefit of as much discussion as possible while the proposed recommendation is being formulated. We will appreciate it if those having any criticisms, suggestions or comments to make on the report will send them to us promptly at the office of the Society.

TRUCK DIVISION

MOTOR-TRUCK CABS

(*December issue of* THE JOURNAL, *p.* 547)

THE DISCUSSION

MR. WHITTEN:—The subject of Motor-Truck Cabs is one on which the Division has done considerable work. It was thought that we had reached a point where a recommendation could be made. We have since found that certain dimensions in the report do not seem to be acceptable, and at a special meeting of the Division yesterday it was decided to withdraw the recommendation for the time being. If possible, cab dimensions will be included also for speed-wagons, making three sizes of cab to cover all requirements from speed-wagons to 6-ton trucks.

ATTENDANCE AT MEETING

The members of the Standards Committee and the Society and the guests in attendance were

Standards Committee Members

Azel Ames
F. W. Andrew
T. L. Lee
B. M. Leece

B. B. Bachman
J. T. R. Bell
R. M. Bird
G. R. Bott
A. K. Brumbaugh
H. E. Brunner
Earle Buckingham
T. V. Buckwalter
J. S. Burdick
R. S. Burnett
R. J. Burrows
C. C. Carlton
E. R. Carter
D. F. Chambers
W. A. Chryst
E. L. Clark
C. F. Clarkson
A. L. Clayden
L. W. Close
J. Coapman
W. F. Cole
P. J. Dasey
B. H. DeLong
H. E. Figgie
J. B. Fisher
Bruce Ford
C. B. Franklin
J. R. Freeman
E. S. Fretz
D. E. Gamble
C. F. Gilchrist
F. P. Gilligan
W. E. Gossling
F. W. Gurney
W. S. Haggott
C. A. B. Halvorson, Jr.
A. W. Herrington
W. H. Herschel
S. P. Hess
C. B. Hoxwood
W. E. Holland
M. C. Horine
L. S. Horner
H. S. Jandus
E. J. Janitzky
E. A. Johnston
L. S. Keilholtz
H. B. Knap
F. C. Kroeger
G. L. Lavery
A. D. T. Libby
F. E. McCleary
W. A. McKay
H. R. McMahon
K. G. Mackenzie
C. M. Manly
G. J. Mercer
C. A. Michel
A. H. Miller
G. L. Miller
F. L. Morse
H. C. Mougey
C. T. Myers
F. F. Murray
A. J. Neerken
I. M. Noble
G. L. Norris
Leonard Ochtman, Jr.
W. C. Peterson
W. M. Petty
W. H. Phillips
H. M. Pierce
H. S. Pierce
H. L. Pope
L. C. Porter
W. B. Price
W. D. Reese
O. J. Rohde
C. B. Rose
J. L. Rupp
C. F. W. Rys
A. J. Scaife
A. W. Scarratt
M. H. Schmid
Louis Schwitzer
J. W. Stack
J. C. Stearns
L. M. Stellmann
W. R. Strickland
Alex Taub
G. W. Vinal
Edward Wallace
J. M. Watson
E. W. Weaver
W. R. Webster
E. E. Wemp
J. A. White
F. A. Whitten
F. G. Whittington
Ernest Wooler
O. W. Young

Society Members and Guests

C. D. Addams
C. M. Ahlene
C. E. Banta
George Bell
Norman Bell
C. M. Billings
B. H. Blair
A. B. Breeze
W. J. Bryan
N. B. Burkness
Henry Chandler
H. E. Clay
K. H. Condit
R. C. Cornforth
G. H. Cottrell
R. H. Cunningham
M. P. Davie
P. H. Davis
W. H. Eiseman
M. P. Ferguson
T. B. Fordham
C. K. Francis
D. J. Gilbert
G. Walker Gilmer, Jr.
A. N. Goodfellow
C. S. Grove, 3rd
F. A. Groves
G. V. Hancock
J. E. Houser
J. H. Hunt
R. K. Jack
W. P. Kendall
G. W. Klinger
B. Kulmow
R. P. Lansing
A. J. Lavoie
L. C. Marshall
R. L. Maxon
E. V. Pannell
R. E. Plimpton
J. R. Reyburn
C. W. Rice
O. C. Rohde
R. F. Russell
J. E. Schipper
J. M. Schoonmaker, Jr.
E. M. Schultheis
R. A. Shailer
Arthur A. Skinner
F. S. Slocum
F. G. Smith
W. Stacker
G. A. Ungar
M. P. Whitney
H. M. Williams
A. D. Wilt, Jr.
C. H. Young

SOCIETY MEETINGS

THE ANNUAL MEETING

Registration Large and Great Interest Displayed by Those Who Attended

Go-getters are men who know what they want and then go and get it. The Annual Meeting was a meeting of go-getters. Attendance at this meeting constitutes star performance in automotive go-getting. There were more than 600 star performers this time. They knew they wanted additional automotive engineering and commercial knowledge, to secure the maximum number of contacts with the good, live, uptodate, automotive data that were presented, to meet other go-getters and to talk things over. So, they came and got all these desirable results, and more! They got inspiration for future effort; inspiration is all that keeps any of us in the go-getting class. New ideals, new ideas, new plans and purposes are continuously necessary to our existence and to our progress and, since they come to us so seldom, most often we must go and get them. Those who seek, will find. In this instance, as in the many previous ones, each man who attended was well rewarded.

Beginning with the usual all-day session of the Standards Committee, on Jan. 9, the results of which are annually so important and so far-reaching, the program of the week, replete with engineering and human interest, was carried through whole-heartedly and successfully to its conclusion on Jan. 12, following the presentation of the unusually complete papers and discussion that constituted the session devoted to engine cooling.

The business session held on the morning of Jan. 10 was of more than ordinary interest, a summary of the work of the past year and an outline of the Society's plans for the year to come being presented. The following outline of what transpired as the program of the 1923 Annual Meeting unfolded is an illuminating record of automotive progress and an earnest of greater achievement yet to come.

MEMBERSHIP CONDITIONS SATISFACTORY

Slightly More Names on Roll Than Last Year

The report of the Membership Committee, which was presented by L. C. Hill in the absence of Chairman Lon R. Smith, is given below.

Membership Department Summary

On Dec. 31, 1922, there were 5135 members of the Society, excluding Enrolled Students and including Service Members, Foreign Members, Members, Associates, Juniors, Affiliate Members and Affiliate Member Representatives. The addition of 214 Enrolled Students bring the overall total to 5349, 32 more than last year.

Service Members, Foreign Members and Affiliate Member Representatives show an increase of 23, 14 and 9 respectively. On the contrary, Members, Associates, Juniors, and Affiliate Members show a decline of 50, 39, 47 and 2. The greatest numerical increase, 124, is in Enrolled Students, contrasted with a decrease of 92 for all the other grades combined.

The above are net figures showing final totals after the subtraction of the following: Deceased, 12; Resigned in good standing, 166; Dropped as delinquents, 480; and Cancelled, 22. The total deduction is, therefore, 680.

Campaigns

In the earlier part of the year, the Society conducted a campaign to enroll more of the major executives of the industry. We have added five of the most prominent in the past year.

We are also conducting a campaign in the passenger-car field, as an investigation showed surprisingly few passenger-car men on the Society's roster, relative to the total membership.

The Society should be able to increase the number of production men on the rolls considerably during the coming year. The national Production Meeting held in Detroit on Oct. 26 and 27 was attended by 248 non-members who should be good prospects, especially as the Detroit Section is planning a number of production meetings to develop the interest aroused by the first meeting.

Grade	Dec. 31, 1920	Dec. 31, 1921	Dec. 31, 1922
Service Members	18	65	88
Foreign Members	50	67	81
Members	2,706	2,723	2,673
Associates	1,495	1,509	1,470
Juniors	692	671	624
Affiliate Members	112	107	105
Affiliate Member Representatives	117	85	94
	5,190	5,227	5,135
Enrolled Students	41	90	214
	5,231	5,317	5,349

ACTION ON RECOMMENDED STANDARDS

Practically All Division Reports Approved as Submitted

At the meeting of the Standards Committee on Tuesday, Jan. 9, 17 Divisions submitted reports for Standards Committee action, 30 recommendations being approved in original or amended form, and one recommendation being referred back for further consideration to the Division that formulated it. With the exception of the report of the Chain Division and the recommendation of the Lighting Division on Tail-Lamp Illumination, the reports were printed in the December issue of THE JOURNAL.

The Ball and Roller Bearings Division report on Metric-Type Thrust Ball Bearings caused a considerable amount of discussion, principally with regard to the policy in American standardization of setting up standards in the metric system. Discussion indicated rather an even division of opinion, and it was finally voted to refer this report back to the Division.

The Chain Division report, which was not completed in time for publication in the December issue of THE JOURNAL, consisted of several parts relating to the mini-

mum breaking-strengths of roller-chains and to standard sprocket tooth-forms and cutters for them. The recommendations involve revisions of the present standards as published in the S.A.E. HANDBOOK. The report, the presentation of which was accompanied by lantern-slides illustrating the application of the recommendations, was approved.

The report of the Lighting Division on Tail-Lamp Illumination was submitted at the meeting in mimeographed form, it having been formulated too late for inclusion in the December issue of THE JOURNAL. The recommendation was based on joint action of the Illuminating Engineering Society and the Society, largely at the request of one of the New England States, because of recent legislation enacted relating to the approval of automobile tail-lamps and registration-plate brackets. It was felt that it is important to have standard specifications in this connection inasmuch as many of the States, which are considering relevant legislation, can probably be favorably influenced toward using a standard specification. It is important to note that the Society has not gone further than to participate in the preparation of what the Division considers a suitable technical specification for testing tail-lamps and tail-lamp illumination. The Division's report was approved as presented.

The report of the Lubricants Division on standard specifications for Crankcase Lubricating Oils was discussed at considerable length with regard to the explanatory grade-names used in conjunction with the proposed specification numbers for the several grades of oil. Modifications of the explanatory grade-names were suggested, but were not generally favored. The report was finally approved for adoption as S.A.E. Recommended Practice, with the omission of the explanatory grade-names.

The Truck Division recommendation for Motor-Truck Cabs was withdrawn as a recommendation for adoption and presented as a progress report only, as a result of recent action taken by the Division.

A progress report was submitted also by the Axle and Wheels Division, on Differential Gears, lantern-slides being shown of the tentative recommendation as printed in the article on Current Standardization Work in the January issue of THE JOURNAL.

The detailed discussions of the Division reports, together with the complete recommendations submitted for action subsequent to the publication of the December issue of THE JOURNAL, are printed elsewhere in this issue. A mail vote on the final adoption of the reports will close on March 12. All of the Society Members who are entitled to vote will be furnished letter-ballots in accordance with the regulations governing the Standards Committee.

GREATER INTEREST IN MEETINGS SHOWN

More and Better Papers Offered for Presentation — Plans for the Future

C. F. Scott, chairman of the Meetings Committee, reported that seven Society meetings were held during the year 1922 as compared with five in the previous year. The Production Meeting was a new development and, he hoped, the beginning of like meetings. This meeting was highly successful, the attendance at the technical sessions being as large as that of some of the technical sessions at the Annual and Semi-Annual Meetings of the Society. The general character of the technical papers presented at the meetings he stated was better than before; and the Committee was in receipt of numerous offers of papers for presentation at the meetings of the Society.

A regional meeting is to be held at Cleveland in April. The subject will be transportation, the plan of conducting the meeting being along the same general lines as that for the Detroit Production Meeting, with technical sessions in the morning and visits to factories in the afternoon.

The time and place of the holding of the 1923 Summer Meeting have not been determined as yet since the main factor entering into the selection of places for the Summer Meetings of the Society has become the recreational facilities available rather than central location.

SOCIETY OFFICERS FOR 1923 ELECTED

A Greater Number of Ballots Cast Than at Any Previous Election

Immediately after the convening of the business session on Wednesday morning, Jan. 10, President B. B. Bachman, who was in the chair, appointed L. S. Keilholtz, J. A. Anglada and C. E. Heywood as tellers of the election of officers to serve during this administrative year and of councilors to serve during 1923 and 1924.

After canvassing the ballots the tellers reported that 952 ballots had been cast, 32 of these being void. The total count on the election, with scattering votes, was as follows:

President

H. W. Alden 917

First Vice-President

H. M. Crane 917

Second Vice-President Representing Motor-Car Engineering

A. F. Masury 916

Second Vice-President Representing Aviation Engineering

E. P. Warner 915

Second Vice-President Representing Tractor Engineering

A. W. Scarratt 917

Second Vice-President Representing Marine Engineering

E. J. Hall 917

Second Vice-President Representing Stationary Internal-Combustion Engineering

L. W. Witry 916

For Members of the Council
(To serve for 2 years)

A. J. Scaife 920
W. A. Chryst 917
F. W. Gurney 917

For Member of the Council
(To serve for 1 year)

H. M. Swetland 919

For Treasurer

C. B. Whittelsey 920

SOCIETY'S FINANCIAL CONDITION SOUND

Deficit for 1922—Income and Expense Approximately Equal Now

The Treasurer's Report was presented in the form of a brief summary, which is given below, by General Manager Clarkson in the absence of the Treasurer, C. B. Whittelsey, who was unable to attend on account of illness. This report, which was printed in the January issue of THE JOURNAL, indicates a sound financial condition.

The annual audits of Rankin & Co., public accountants, list the assets of the Society at approxi-

mately $154,000 on Sept. 30, 1922, and $156,000 on the same date of 1921.

These were offset by debts of approximately $31,000 in 1922 and $17,000 in 1921, leaving an unexpended reserve of approximately $122,000 at the close of the last fiscal year, which was about $15,000 less than on Sept. 30, 1921.

The Society's income for the fiscal period ended Sept. 30, 1922, was in round numbers, $248,000 and for the preceding fiscal period $243,000.

The expense for the same period was $263,000 in 1922 and $233,000 in 1921, leaving a deficit in 1922 of about $15,000 as compared to unexpended income of about $10,000 in 1921.

On Sept. 30, 1922, the Society owned Government and railroad bonds having a par value of $78,000 and a market value of $76,000. Ten thousand dollars has been invested in securities since Sept. 30, bringing the total up to $88,000.

There has been very little relative change in the status of the Society's finances since Oct. 1. The income for the first three months of this fiscal year was approximately the same as the expense. We hope to keep the expense within the income figures throughout the year and at least to be able to show no loss at the end of the current fiscal period.

PROBLEMS OF THE SECTIONS

Section Dues, Appropriations and Affiliation with Other Local Bodies Discussed

A. K. Brumbaugh, Chairman of the Sections Committee, presented the following report:

No new Sections were formed in 1922, but the ones in existence at the start of the year have each carried through a series of valuable Sections Meetings. A better appreciation of the value of Sections Meetings has been evidenced by the members and the growing importance of Sections as an activity of the Society has been appreciated in a greater degree by the Council. A number of important problems, many of them fundamental, have arisen during the year. All of these have been carefully studied by the Committee and referred to the Council with definite recommendations as to their solution.

The suggestion that Section dues should be waived has received support from several sources during the year. The Sections Committee studied the matter with care and voted to support the present practice of charging $5 for annual dues in each of the Sections. The major part of the administrative expense of the Sections is now borne by the national treasury. It is believed unfair to have all Sections' expenses covered by national dues, for the reason that a large percentage of the members in the Society are never able to enjoy the privileges of Section membership, due to their residence in cities that are not served by the local Sections. The most equitable solution seems to be to ask the local members to pay dues in the Sections for the privilege of attending Sections Meetings.

Having supported the charging of Sections dues, the Committee was faced with the problem of placing some tangible value on membership in the Sections so that the officers of the Sections would find it easier to collect dues. It was found that many members of the Society continued to enjoy the advantages of attending Sections Meetings after having refused to pay dues to the Section. This practice, logically unfair, resulted in the Metropolitan Section charging admission to its meetings for Society members who were not members of the Section. The Detroit Section instituted the practice of asking each member for his Section membership-card at the door of the meeting and insisting that he request one of the members of the Section to invite him into the meeting as a guest, if he was not a member of the Section himself. The officers of the Metropolitan Section seem to be agreed that their scheme is working satisfactorily. The Detroit Section found that its practice resulted in a number of additional members joining the Section. The Council now has this whole matter, outlined above, under consideration.

Study of the financial reports of the Sections on Sept. 1 showed that the past methods of appropriating money from the National Society to each of the Section treasuries had not been equitable. Some of the smaller Sections were given more money than they needed; and one or two of the larger Sections were given insufficient funds and found it necessary to raise money by subscription to offset their deficits. After careful study, the Sections Committees recommended to the Council that future appropriations to the Sections be made according to the following formula: A basic appropriation of $250.00 to each Section; $1.00 for each member of the Society residing within the Section territory as designated by the Council; and $2.00 for each member of the Section who had paid his Section dues by April 1.

Checking the appropriation as computed by this formula against the funds claimed to be needed by each of the Section treasurers, it was found that the national appropriation, combined with the local Section dues, would suffice to take care of the expenditures of all of the Sections. This formula plan has been approved by the Council.

During 1922 a number of the Sections were asked to amalgamate with other Sections of national engineering societies in what are known as local engineering clubs or associations. The object in each case was to have the clerical work of all of the associations taken care of by a single paid secretary with a consequent reduction in overhead to each of the Sections. In each case these local engineering associations have established club-rooms for the holding of engineering meetings. The Buffalo, the Cleveland and the Mid-West Sections have joined such associations. The Detroit Section decided against such an affiliation because of the belief that the Section was sufficiently large to carry its own overhead and that any affiliation would result in diminishing of the Section prestige. The Sections Committee has regarded favorably any affiliation with local engineering associations, provided the identity of the Society were not lost or interest in its activities as a Society diminished.

Requests have been received from at least two of the Sections for the approval of some form of local membership in the Section for men who are not members of the national Society. It will be recalled that at one time the Sections had such a form of affiliation, known as Section Associateship. This form was discontinued because its privileges were often abused by men who felt that they enjoyed the same privileges in the Society as its members. A reestablishment of this practice would be replete with problems. It has been suggested that such local Associates should not be extended any privilege other than attendance at local Section meetings. THE JOURNAL would not be mailed to them and they could not attend national meetings of the Society without payment of the customary fees for non-members. The Washington and the Detroit Sections feel that there are a number of men in their territories who would contribute to their financial support by paying for the privilege of attending the local meetings. The interest of these men in the Society is purely a local one; they seldom attend national meetings; in many cases they are young men unable to pay the more costly dues to the national Society. No decision has been reached in this matter, for it is of recent origin; however, the 1923 Sections Committee will recommend some definite action to the Council.

In general, with few exceptions, the officers of the Sections during the year 1922 have shown praiseworthy devotion to their responsibilities. The character of pa-

pers presented at Sections meetings has constantly improved; and authors must have something meritorious to present before they are accorded the privilege of addressing Sections meetings. Service to the Sections on the part of the Society staff has been broadened. Assistance is given in the selection of meetings topics and speakers and in soliciting Section membership. Publicity service on Sections meetings, in THE JOURNAL, the trade press and the newspapers, has been extended by the staff organization to the Section secretaries. A Sections Bulletin has been created for the purpose of circulating items of interest among the Sections officers and committeemen periodically. The Sections meetings are being reported more fuly in THE JOURNAL of the Society, the salient points in the papers and discussion being stated.

The Sections Committee of 1922 has been impressed with an increasing importance of the Sections as outposts of the national Society. Sections meetings will increase in value and prestige until they are close rivals of the national and regional meetings of the Society. It will be considered as much of an honor to present a paper before a meeting of a Section as before one of the national meetings. Section activities will develop a stronger local interest in the affairs of the national Society and result in the strengthening of its position in general.

WHAT CAUSES WHEELS TO WABBLE

Ball-and-Socket Joints and Elimination of Castering Suggested as Remedies

Following the Business Session, the paper by Herbert Chase, entitled Critical Study of Modern Automotive-Vehicle Steering-Systems, was presented by the author and discussed. In presenting this paper Mr. Chase pointed out that steering-systems as a whole have changed but little for many years and inasmuch as the conventional layout has operated with reasonable satisfaction in most cases it has been given relatively little attention. Among the common faults of the steering-system is the excessive effort required in its normal operation, the primary causes of hard steering being friction and faulty design of the system. The use of anti-friction bearings of both the ball and the roller type in the steering-gear to take thrust and also radial loads was commented on, after a brief discussion of the causes of hard steering, such as incorrect location of steering-arms and distortion of the various parts of the steering system, under either the load of the vehicle or that imposed by the steering operations, the weight of the front wheels of the vehicles and the length of the moment-arms. Mr. Chase then took up the question of the angular position of the knuckle-pivot and the locating of the knuckle-pivot as close to the central plane of the wheel as is reasonable without involving unnecessary expense.

One of the most common faults of the steering system and one whose causes are least understood, said Mr. Chase, is that of wheel wabble, which is the periodic oscillation in the angular position of the wheel and the axle spindle about the knuckle-pivot, the result being that the wheel follows a course which deviates alternately to the right and the left of a straight line. The three primary causes of wheel wabble according to Mr. Chase are (*a*) unstable equilibrium of wheels carried on knuckles with inclined pivots, (*b*) faulty layout of drag-links with reference to the springs and (*c*) a lack of balance or failure of the wheels to run true. In discussing the question of drag-link location Mr. Chase said that the best layout is the one which causes the least motion at the wheel spindle about the knuckle-pivot when the axle is moved under the influence of the spring action.

In opening the discussion of the paper, Cornelius T. Myers emphasized the importance of brakes and steering mechanisms from the standpoint of safety. He thought that a feature of major importance in the layout of the steering mechanism is the relation of the travel of the ball on the steering-knuckle arm when under the influence of the spring vibration to the ball on the arm of the steering-gear itself. The arc followed by the spring-seat and that described by the outer ball in the drag-link should coincide as closely as possible for a distance equal to the usual movement of the springs. The tendency to wabble is due largely to the varying amounts by which these two paths diverge in any particular steering layout.

Another point brought out by Mr. Myers was that the wabbling seems to be greatest when there is a perceptible amount of wear in the steering-pivot bushings, the wheel bearings, the tie-rod connections and similar parts. When successive bumps or depressions in the road surface synchronize with the taking up and giving out of the total amount of wear or slack, the wabbling seems to be most severe and somewhat analogous to snapping a whip or more directly to snapping a chain in which the links are long in proportion to their width.

Unbalanced forces set up in the front wheels by the weight of the tire-valves and adjacent parts also in his opinion exert an influence on wabbling; he is still experimenting upon this point. As the wheel spindles are not horizontal these unbalanced weights move toward and away from the chassis as the wheels revolve, it being apparent that when the position of the valve in the left wheel bears a certain relation to the position of the valve in the right wheel the forces set up as these valves revolve tend to counteract each other and balance, although on the other hand the relative location of the two valves might be such that two forces would be additive. In support of this he mentioned cases where wabbling had started on comparatively smooth concrete roads when the car was driven in one direction but no wabbling had occurred when the car was turned and driven over the same stretch in the opposite direction at the same speed. When this wabbling occurred on smooth hard roads it usually took place at nearly double the speed at which it took place on rough roads.

In his opinion the conditions under which violent wabbling takes place depend upon a number of different factors such as the steering layout, the inequalities of the road, the vibration period of the springs, the speed of the car, the weight of the front end of the car, the moment of inertia about the vertical axis, the tire inflation and the wear and looseness of the front axle and the steering-gear parts. While often minor changes of one kind or another apparently cure the trouble, it is latent if the steering mechanism is not correctly laid-out, and will reappear under somewhat different conditions than at first. One way to minimize wabbling is to turn the car steadily and not too sharply to one side or the other. In this connection it was pointed out that it is best as a rule to drive on the right side of a crowned road so that a little left-arm pull on the steering-wheel must be exerted continually to maintain a straight course. In this way the slack is taken out of the loose steering connections and any wabbling due to looseness only obviated, while a further turning toward the left or the crown of the road will take any slack produced when wabbling is started by impressed vibration from road bumps and often damp out the wabble before it becomes severe.

H. A. HOLLOWAY O. C. BERRY E. P. WARNER T. J. LITLE, JR.

S. D. HERON H. M. CRANE S. M. LEE G. E. GODDARD

D. P. BARNARD, 4TH H. W. ALDEN B. B. BACHMAN E. H. LOCKWOOD

G. J. MERCER C. S. KEGERREIS O. M. BURKHARDT V. H. GOTTSCHALK

R. E. CARLSON HERBERT CHASE S. W. SPARROW THOMAS MIDGLEY, JR.

In continuing the discussion, Prof. E. P. Warner pointed out that looseness in the steering-gear is not the only cause of wabble, since a motorcycle with a rigid steering-gear is subject to this phenomenon, as is also the bicycle. Mention was also made of the British scooter on which the operator stood on a platform where the vehicle became entirely unmanageable at speeds above 12 m.p.h. In connection with the wabbling of motorcycles and bicycles it was pointed out that the wabble was cured by changing the curvature of the fork, which was the same thing as eliminating the castering effect in an automobile.

M. C. Horine took exception to Mr. Chase's recommendation that anti-friction bearing be used in steering-gears since, he stated, they tend to produce hard steering. He did not agree with the use of a center-point steering arrangement, saying that it is difficult to operate easily at low speeds as the action is that of grinding rather than rolling the wheel about a point. The toeing-in or foregather of the wheels is a problem of the automobile industry only, as apparently the builders of horse-drawn vehicles solved it satisfactorily in their field some time ago. One cause of wheel wabble, Mr. Horine believes, is the use of standard front-axles for vehicles of different wheelbases, thus producing a varying angularity of the steering-arm. He took exception to Mr. Myers' statement regarding the ranking of brakes before the steering mechanism from the viewpoint of safety, stating that personally he would much prefer to be able to steer a vehicle and trust to being able to stop it, than to have means for stopping the vehicle and not be able to steer it. He also mentioned the use of the straight fork on a certain make of motorcycle about 15 years ago as a successful means for curing the wheel-wabble that caused trouble. In this arrangement the center line of the fork was extended to intersect the axle, instead of coming behind it and intersecting the road at a point in front of the point of tire contact.

O. A. Malychevitch said that irreversibility is an important factor in steering and mentioned the Schneider steering-mechanism employed on the Paris omnibuses as a good example of mechanism in which no wabbling occurs.

Exception was taken by O. M. Burkhardt to the statement made by Mr. Chase that road shocks in the plane of the wheel have a minimum moment about the knuckle-axis and consequently are transmitted in a less degree to other parts of the steering mechanism. He stated that while the moment is less it is transmitted more completely. The amount of foregather can be determined easily by geometric methods. In his opinion, bearing loads are very important in the effect that they exert on the action of steering mechanism.

A. J. Scaife spoke of the experience of the White Co. with a ball-and-socket joint on the steering-rod end. He stated that after being used for some time the ball became oval and the steering was cramped, thus leading the White organization to abandon this construction. Wheel-wabble is extreme with loose mechanism; he cited a case where a taper wedge inserted between the spring and the spring perch on the front axle had eliminated the wabbling, whereas taking up the joints had not proved successful.

L. H. Pomeroy spoke of the possibilities of shackling the spring at the front end as in the De Dion car and also in the buses used by the Fifth Avenue Coach Co. in New York City. He pointed out that the angle at which the steering-arms and their projection intersect the axis of the chassis exert a considerable influence on wheel-wabble. In support of this he mentioned a case where the projections of the steering-arms intersected the chassis axis at a point distant from the front axle an amount equal to 56 per cent of the length of the wheelbase and the wheels wabbled very badly, while by changing this position of intersection to 62½ per cent of the wheelbase satisfactory results were obtained. In his opinion wheel wabble results from two or three contributary causes and not from one alone. He cited a case where a car that wabbled badly when equipped with demountable wheels and rims was rendered entirely free from this phenomenon by the use of standard wheel equipment. Another cause of wheel wabble was the maintaining of an unnecessarily tight grip on the steering-wheel by the driver.

Dr. H. C. Dickinson discussed the question of wheel-wabble from the viewpoint of the application of the fundamental laws of harmonic vibrations. He pointed out that the periodic wabble of the wheel must follow the law of a pendulum and tend to return. When a system is forced out of position there is of course a force tending to restore it to its normal state but the damping exerted by friction is not greater than this force of restitution. In his opinion there would be no wabble if there was no castering action and a completely irreversible steering gear would not wabble. Wabble would likewise be absent if friction in the system were greater than the force applied to maintain the vibration of the system. In support of Mr. Pomeroy's theory that a hard grip of the steering-wheel may be responsible for wheel-wabble, Dr. Dickinson pointed out that such a grip of the wheel would induce wabble since the physiological reaction applies a greater force to return the road wheels to their proper position than that which throws them out. Another cure for wheel-wabble is to provide in the system for a resistance to motion that is greater than the force tending to throw the wheels out of position. Abnormal sidesway also reinforces the normal tendency of the wheel to wabble.

Mr. Chase in concluding the discussion stated that in his opinion the castering angle does affect wabble, thus taking exception to Mr. Myers' statement. In support of his position Mr. Chase cited an instance where a car was absolutely out of control with a castering angle of 10 deg., while changing this angle cured the wheel-wabble. The usual angle varied from 1½ to 3 deg., although 6 deg. was a maximum. In reply to Mr. Horine Mr. Chase stated that the use of anti-friction bearings shows that they are practical and that the proper size of bearing will reduce the effects of corrugation mentioned by Mr. Horine. The laying-out of the drag-links is a geometrical problem and there are a number of lay-outs that will operate more or less satisfactorily. The drag-link arrangement shown in the paper in which the steering mechanism was in front of the front axle is in Mr. Chase's opinion a very good arrangement. Placing the steering-gear back of the axle would be better if it were possible to shackle the spring at the rear end, although he considered the arrangement of front shackling proposed by Mr. Pomeroy as being desirable under certain conditions. In Mr. Chase's opinion the proper lubrication of the ball-and-socket joint in the steering-mechanism will minimize the wear and it is no more difficult to replace a ball when it becomes worn out-of-round than it is to replace a pin in the pin-and-yoke type. A further advantage of the ball-and-socket construction is that a socket with a spring-backing provided for continuous taking-up of the wear. In conclusion Mr. Chase stated that even if there were no castering wabble would occur.

COMMERCIAL-AIRPLANE DESIGN

How Economical, Safe, Speedy and Comfortable Machines Should Be Built

At the aeronautic session held on the evening of Jan. 9, Prof. E. P. Warner discussed commercial airplane design in general terms, under the main divisions of economy, safety, speed and comfort, in presenting his paper on the Design of Commercial Airplanes. He mentioned possible reductions of first cost by designing for long life and reliability, the effect of the former on the depreciation allowance being obviously advantageous. Safety was stated to be dependent upon reliability, structural strength, stability, control, fire prevention and the reduction of the risk of injury to passengers in the event of a crash. Minimizing the bad results of a crash were considered suggestively. He believes that, since speed is governed almost solely by the ratio of wing loading to power loading, speed will always be kept as low as possible without any loss of business to competing companies. Among other desirable measures to secure comfort, he specified adequate ventilation and the elimination of noise.

CREATING A DESIRE TO FLY

An Outline of a Possible Public Commercial-Airplane Demonstration

The second paper at the aeronautic session, by C. G. Peterson, presented immediate possibilities in the way of commercial-airplane service. Stating that the heretofore impossible barriers to commercial aviation have been costs and the lack of desire of the public to fly often, or to fly at all, Mr. Peterson proposed that the public, which must constitute the market for airplanes on a commercial basis, be educated by a demonstration of safe and reliable, pay-load airplane-service extended over an indefinite period, and outlined a plane that includes the surmounting of cost deterrents.

He marshaled arguments and statistics to show that such a public demonstration can be made by a proper and adequate equipment, operation and maintenance of the United States Aerial Mail Service, since it has been demonstrated already by this service that mail can be carried safely by air throughout hard Northern winter weather.

His statistics include consideration of the present volume of mail, special-delivery-letter and parcel or package-carrying possibilities as revenue producers, and necessary postal rates.

An extensive estimate of the cost of equipping and operating a night-flying line between New York City and Chicago, based on present equipment, was presented. The author expressed the belief that passenger traffic will follow, without any solicitation on the part of the operators, just as soon as the public realized that the mail airplanes fly safely and on time.

COMPETITIVE BIDS HURT AVIATION

Does Government Procedure Discourage Rather Than Encourage Development?

In his aeronautic-session paper on The Development and Construction of Military Airplanes in Peacetime, F. H. Russell considered the reconstruction period following the war and the conditions prevailing on Jan. 1, 1923. Present conditions were stated to be far from satisfactory because of Government competition with the aeronautic industry and lack of appreciation of both the necessity for and the requirements of a healthy industry.

The solutions proposed by the author are (*a*) that Government agencies inspire and direct the industry in the development of the types desired and the peacetime supply thereof, through the operation of equipment; and (*b*) that airplanes of one type such as a type of engine or automobile, be considered as proprietary and not subject to open competitive bidding.

Mr. Russell summarized the current situation in regard to conditions most detrimental to progress. His view of the peacetime problem of the Government engineer is that it involves first the selection of those types of planes which are required for actual military training and operations; and, second, the guidance and support of the industry toward the development of such designs, having in mind constantly that the airplane developed must not only be satisfactory for the service desired, but be designed in detail so as to be suitable for quantity production.

With regard to civilian aircraft organizations, the author stated that they must consist, not only of a capable group of creative engineers, but also of men trained and experienced in manufacturing. The physical facilities should include wind-tunnels and aero dynamic, physical and chemical laboratories, and also the latest types of production machinery. Any separation of engineering from production, such as is found in connection with types of airplane developed by small engineering units, or production without adequate creative engineering, Mr. Russell believes, is bound to result disastrously. The two must go together. In his opinion, the Government should establish a policy whereby, under proprietary orders, a company can specialize in the development of one design or class of aircraft, build it continually in small quantities, and improve it. He stated that such a civilian organization should be required to furnish standardized specifications, blueprints, bills of material and the like which, in time of national emergency, could at once be placed in the hands of executives controlling factories outside of the industry for quantity production.

SAFE FLYING A PRESENT PUBLIC ASSET

Regular Aerial Transportation of Passengers Over Water Accomplished

A widely prevalent barrier to the success of commercial aviation was stated by Harry Bruno, in his aeronautic-session paper, to be the difficulty of convincing the public that we have successful commercial aviation now. As a representative of an aerial-transportation company now maintaining regular service over water, he believes this country to be ahead of Europe in regard to over-water aerial-transport. His company maintains in service 27 flying-boats that have, in the past 3 years, made 2125 flights, carried 9107 passengers and flown 739,047 passenger miles without any injuries or deaths resulting.

He said that the actual cost of gasoline and oil, maintenance and depreciation is small compared with the cost of persuading the public to come to the starting-points of the different routes, that the public does not demand a speed of more than from 65 to 90 m.p.h. and that the

ordinary individual cannot comprehend a speed as great as 125 m.p.h. His belief is that the public is favorably inclined toward flying, and that successful operation, as in the case of the 700-mile mail-and-passenger service now conducted in South America, will eventually cause a change in public sentiment. In further support of this belief, he said that during the first month of the flying service between Cleveland and Detroit, a 90-min. trip, the passengers were mostly women and children; but that during the second month of operation the passengers were mostly business-men.

A further possibility in the development of commercial aviation was stated to be service as an adjunct to railroad operation.

GENERAL COMMENT ON AERONAUTICS

Some Interesting Views Expressed by Members in Attendance

C. M. Manly was a leader in the discussion at the aeronautic session. He emphasized the need of selling the idea of commercial aviation to the public, inclusive of the farmer and other people in the rural districts, and made suggestive comment upon the aeronautic situation in general.

R. R. Blythe spoke of the inconveniences incident to starting on an aerial trip and of the necessity of minimizing them in line with encouraging passengers to travel in this way. He believes that regularly operated aerial express-lines would be most helpful in securing public confidence in aeronautics.

C. D. Hanscom discussed postal rates in connection with Mr. Peterson's paper and believed that a letter could be carried by aerial mail between New York City and Chicago for 0.8 cents.

Archibald Black discussed Professor Warner's statement that

> At present it seems impracticable to realize a commercial speed of more than 85 m.p.h. on lines running without subsidy, as the costs of operation at higher velocities than that become prohibitive.

Mr. Black thinks that a speed of 105 or 110 m.p.h. can be maintained without increase in the cost.

Edward Shildhauer suggested a lighter-than-air aircraft service as a backbone between such points as New York City and Chicago, supplemented by airplane service radiating from such terminals; the main-line flying to be done at night, with arrivals at dawn, and the airplane service to start at dawn, with return-trips each afternoon.

Other expressions by representative men in attendance included a suggestion that an appeal for commercial aviation be made to the sporting blood of the public, that unusual markets for aircraft service can be unearthed, such as patrol and photographic service, and that difficulties incident to aircraft flying in fog and at night be overcome.

MEASURING MOTOR-FUEL VOLATILITY

Further Data on the Initial-Condensation Temperatures of Various Mixtures

The first paper presented at the fuel session on Thursday afternoon, Jan. 11, was by R. E. Wilson and D. P. Barnard, 4th. In this paper, which was presented by Mr. Barnard, the method for measuring the dew-points or initial-condensation temperatures of motor-fuels when mixed with air in various proportions as outlined in an article by these authors that appeared in the November, 1921, issue of THE JOURNAL was extended to include a larger number of fuels. In the earlier article only three fuels were considered, while in the paper presented at this session the results of an investigation of 14 fuels ranging in volatility from the lightest aviation gasoline to a rather high-boiling commercial kerosene were given. Much of this work was done in connection with the cooperative fuel-research program conducted jointly at the Bureau of Standards by the American Petroleum Institute and the Society. The paper describes certain modifications and improvements in the method previously described for preparing equilibrium solutions and measuring the vapor pressures of motor-fuels. A series of empirical curves from which it is possible to determine, data from the distillation curve being given, the dew-point of a non-aromatic hydrocarbon fuel with a degree of accuracy sufficient for all ordinary purposes, was shown in the form of lantern slides. As a result of the work done by the authors the conclusion is drawn that the 85-per cent point is the best single measure of the effective volatility of a motor fuel from the standpoint of distribution and crankcase-oil dilution. This paper with the illustrations of the curves mentioned will be published in an early issue of THE JOURNAL.

EXPERIMENTAL SURVEY OF CARBURETION

Results Obtained at Purdue University with Kerosene and Gasoline

This paper, which was printed in the January issue of THE JOURNAL, gives in considerable detail the results of an experimental study of the carburetion of gasoline and kerosene as conducted at the Purdue University Engineering Experiment Station. In presenting this paper, C. S. Kegerreis, one of the authors, outlined very briefly the methods employed and exhibited a number of slides that showed the results of the experiments in graphic form.

In opening the discussion, P. S. Tice stated that he did not entirely agree with the points brought out by Messrs. Kegerreis and Young, since he had found that gasoline and kerosene, when used in the same engine with equal temperatures and substantially no fuel liquid on the wall, give equal mean effective pressures and thermal efficiencies with less exhaust-heat lost and proportionately the same loss to the jacket if detonation should occur. He also stated that the mixture-ratios for maximum power and maximum thermal-efficiency under equal-temperature conditions differ only as the calorific values of the fuels. It had been his experience that the maximum efficiency is not obtained at the lower limit of inflammability as stated by Mr. Kegerreis, and he believed that the conclusion arrived at by the latter must have resulted from the limitation of his method of preparing the charge, since his limits represent more fuel in the charge than the proportions found to give the maximum efficiency. Mr. Tice had found that the lower limit of inflammability is quite consistently 0.0445 lb. of kerosene per pound of dry air; a mixture ratio of 1 to 22.5. In view of this fact he was of the opinion that some of Mr. Kegerreis's conclusions on the metering requirements of the carbureter for acceleration and good car-performance under throttle manipulation were in error. In support of these points, Mr. Tice drew a number of diagrams which will be presented in a later issue of THE JOURNAL with his full discussion of the paper. In conclusion he stated that the use of a steady-flow

apparatus is of very doubtful value, particularly if the carbureter is to be used in conjunction with only four or a lesser number of cylinders.

The next speaker, H. S. McDewell, pointed out that the method employed in the paper to reproduce test conditions did not give the usual conditions that obtain in operation, since the throttle plates employed would catch the fuel that crept on the walls of the manifold and cause it to be subsequently vaporized. While the testing plant used by the authors would undoubtedly compare carbureters under the same conditions, these are not the conditions that obtain in the engine.

E. H. Sherbondy, the next speaker, said that the carbureter has two functions to perform; metering the fuel and the air and diffusing the fuel throughout the air. For that reason choke-tubes and sprays had been developed. To determine the loss of pressure across a carbureter he had built an air-meter and tested a number of carbureters of the conventional type. In making these tests he found that the pressure-drop from the entrance to the throat was greater than that through the venturi tube. By changing the form of entrance to the carbureter it was possible to pass as much air through a 1¼-in. carbureter as was ordinarily possible with a 1¾-in. carbureter of the conventional type.

J. G. Willett asked whether it would not be possible to vary the amount of air and fuel handled by the carbureter with changes in the car speed. Mr. Tice in answering this question said that the so-called fuel-lag is responsible for mixtures firing at one speed and not at another.

W. L. Dempsey expressed the view that engines should be improved, as well as carbureters. He pointed to the Diesel engine as the most economical form of power-plant, burning practically any grade of fuel without crankcase wastage. During the burning of the fuel the temperature ranges from 900 to 950 deg. fahr. In the internal-combustion engine the temperature must be kept well above the critical value at which the fuel condenses out of the mixture. At the present time the air and the fuel are mixed in the carbureter and passed on to the manifold where condensation occurs. The drawbacks of the Otto cycle are a waste of fuel into the crankcase and out through the exhaust. To secure satisfactory operation a dry gas is necessary, and if the mixture temperature is maintained above the critical point from the time the mixture leaves the carbureter to that of the end of the compression-stroke, the economy of operation will be increased. In conclusion, Mr. Dempsey emphasized the necessity of supplying sufficient oxygen to form carbon dioxide and water and maintaining a high temperature.

In response to a question by A. D. T. Libby as to whether super-heated steam was fed with the kerosene, Mr. Kegerreis replied in the negative.

Neil MacCoull said that he had noted a temperature-drop of 100 deg. with the air at 250 deg. fahr. He asked whether the spark position was kept constant or advanced in the tests. Mr. Kegerreis stated that the temperature was measured at a point 10 in. from the carbureter; also, that the spark was held at the point to give high power in all cases.

NATURAL GASOLINE AS AN ENGINE FUEL

Utilization of a Product Extracted from Natural Gas Will Relieve Shortage

The last paper presented at the fuel session was read by W. M. Welch in the absence of the author, Lloyd F. Bayer, of the Tidal Refining Co. After pointing out that the problem of securing the largest possible supply of the best possible motor-fuel is one that concerns both the petroleum and the automotive industries, the paper describes the two processes employed to secure natural gasoline, which term is accepted generally by the petroleum industry as applying to the gasoline product extracted from natural gas. The first of these is the compression process, which is applied to casing-head gas and consists in subjecting the relatively rich gas to high pressure and cooling to or below atmospheric temperature, thus resulting in the direct condensation of gasoline. In the other method, which is known as the absorption process, the gas is brought into contact with a heavy oil that originally has no gasoline content. After this oil has absorbed the gasoline it is heated to distill off the gasoline, the two operations of absorption and distillation being continuously repeated within a closed system. The use of natural gasoline to render certain fractions of the crude oil that of themselves would not meet the requirements of an acceptable grade of motor-fuel sufficiently volatile for satisfactory use is gone into at some length. To assure the greater volatility necessary in winter with motor-fuels, particularly those of high end-point, it is desirable to increase the percentage of natural gasoline used. This is practicable since the consumption of gasoline is much less in the winter than in the summer, while the production of natural gasoline increases to some extent in the winter. Mr. Bayer stated that the production of natural gasoline amounts to about 10 per cent of the total gasoline production, and that this is a very satisfactory proportion in which to use natural gasoline with the average motor-fuel to give it the desirable volatility characteristics.

In the past the use of natural gasoline has been attended with varying success, depending altogether upon the intelligence that was displayed in combining it with other products to form the finished motor-fuel. This formerly resulted in the use of a blended fuel that was unsatisfactory for a number of reasons, but the Association of Natural Gasoline Manufacturers is making every effort to produce only blends that will be satisfactory. Dynamometer tests have shown that the addition of 15 per cent of natural gasoline to a good commercial gasoline increases the brake horsepower developed and decreases the fuel-consumption per horsepower-hour. The starting and accelerating characteristics were improved as the percentage of natural gasoline was increased, this improvement being very marked at 10 per cent and reaching a maximum when 15 per cent of natural gasoline was added. Another advantage of the use of natural gasoline is that the initial boiling-point can be lower and the percentage distilled off at 212 deg. fahr. materially increased.

ARE WE INTERESTED IN HIGH COMPRESSION?

Its Effects on the Internal-Combustion Engine Analyzed and Discussed

In opening the session devoted to a discussion of the subject of detonation, Chairman H. L. Horning called attention to the three fundamentals, reaction-velocity, compression and temperature, as the factors influencing detonation. He spoke of how specifically the three papers presented dealt with these factors and asked that they be kept continuously in mind whenever detonation was under consideration.

The paper by J. H. Holloway, H. A. Huebotter and G. A. Young is a report of a series of tests they con-

ducted during the summer of 1922 at the Purdue University Engineering Experiment Station and was published in the January, 1923, issue of THE JOURNAL. The work consisted of research into the operation of internal-combustion engines under comparatively high compression on ordinary gasoline without detonation. The compression-ratio of the engine was 6.75 and the compression pressure was 122 lb. per sq. in., gage. The ingoing charge was passed through a hot-spot vaporizer and thence through a cooler between the carbureter and the valves. Jacket-water temperatures between 150 and 170 deg. fahr. were carried at the outlet port of the jacket.

The source of the two phases of detonation encountered in this work is believed to be overheated areas in the combustion-chamber. The methods of combating these hot spots were stated in detail, and the special equipment applied to the engine to accomplish the desired result was described. The effects of load, speed, compression-ratio and mixture-ratio were studied, and curves showing the variation in the engine characteristics due to each factor were submitted. All these tests were run without a trace of detonation, and the results of the work indicated the following conclusions:

(1) Automobile engines designed to give a uniform cooling of the combustion-chamber walls will permit the use of much higher compression-ratios than those employed at present, with a consequent gain in engine power and economy

(2) The fuel-air ratio for maximum economy borders upon the lean limit for reliable combustion

(3) For maximum power, the mixture-ratio used need not exceed 0.075 lb. of gasoline per lb. of dry air

(4) With concentrated heating of the mixture at the carbureter outlet, a local temperature of 125 deg. fahr. is sufficient to give good operation at full throttle

(5) Cooling to 100 deg. fahr. at the valves is desirable if the compression pressure of the engine is high

(6) At part loads, a hot-spot temperature of 175 deg. fahr., with or without intermediate cooling, will give good results with lean mixtures

WHAT CONDITIONS CAUSE DETONATION?

An Explanation of the Natural Factors That Govern This Gaseous Phenomenon

The second paper presented at the detonation session, by Thomas Midgley, Jr., and Robert Janeway, analyzed the laws that govern gaseous detonation. The authors gave an explanation of detonation based upon what are considered incontrovertible facts, showing by the functioning of well understood natural laws that gaseous detonation is a phenomenon that does not require any hypothetical assumptions to account for its existence.

The physical conditions that must exist within an enclosed container when it is filled with an explosive mixture of gases and these gases are ignited were stated and analyzed mathematically, and an application of this analysis was made to the internal-combustion engine. The apparatus and the procedure were described, inclusive of illustrative views and charts, and it was shown how the formulas can be applied, (*a*) for constant throttle and varying the temperature of the entering charge and (*b*) for constant temperature and varying the throttle opening and the compression-ratio. The results were discussed in some detail. In addition, reference was made to two of the basic equations and they were combined into a single fundamental expression containing only two variables. Further, a mathematical determination was made of the critical pressure of detonation.

SPECIAL ASPECTS OF THE FUEL PROBLEM

Suitable Fuels for Use in High-Compression Engines for Aeronautic Usage

The final paper at the detonation session dealt with testing fuels for high-compression engines. It was written by Stephen M. Lee and Stanwood W. Sparrow, and was read by Mr. Lee; it had been printed in the January, 1923, issue of THE JOURNAL.

The paper treats certain of the methods used and the results obtained in two investigations, the fuels in question being benzol and ethyl alcohol, either alone or as blended with gasoline.

The authors emphasized the necessity of mixture-ratio runs when making fuel investigations. Since the tendencies of a fuel to detonate or preignite limit the conditions under which it can be used, the methods of estimating these characteristics were discussed. A graphical representation was made to illustrate the relation between compression pressure, compression-ratio, volumetric efficiency and indicated power so that, with a given engine, the effect on detonation of changing engine conditions could be estimated.

Results characterizing the performance of the different fuels were mentioned, and particular attention was directed to cases where these results are in contrast with current opinion.

THE BIG NOISE OF CYLINDER DETONATION

Its Causes Analyzed in the Light of Present Knowledge and Research

The discussion at the detonation session verified the prediction made by Chairman Horning that the subject matter would inspire the many prominent members of the automotive and allied industries who were present. The rapid-fire questions and answers that were exchanged between the members of the audience and the authors of the papers gave proof of such inspiration.

Thomas Midgley, Jr., when opening the general discussion, asserted that the physical characteristics of the fuel used must be known and specified for all investigations concerning detonation.

E. D. Thurston, Jr., called for discussion with regard to best power and economy and how they are related to the best fuel.

Dr. H. C. Dickinson read written comment from J. G. Vincent, who was unable to be present, regarding the subject of "rough" engine operation, which was tied to statements regarding this matter made in the Holloway, Huebotter and Young paper, by Chairman Horning.

S. W. Sparrow spoke of the need of recognizing the importance of compression pressure over that of compression-ratio.

S. D. Heron discussed internal engine-temperatures with reference to the shape of the combustion-chamber, and P. S. Tice referred to combustion-chamber shape and the effect of mixture temperature on the high-compression method. Mr. Tice mentioned also that detonation occurs in a definite relation to the initial temperature of the charge; the lower the initial temperature is, the less the tendency to detonate will be.

A lengthy exchange of opinions was had between

numerous discussors regarding whether the high value or the low value was used, or should be used, as the heating value of a fuel under consideration. While no conclusion was reached, the wide variations in practice were made evident.

Many interesting questions and answers referred to the Midgley and Janeway paper, but their details are too intricate for a general report and must be reserved for publication later. It was brought out that the detonation values given by Mr. Midgley apply only to the particular engine that was used, and that these values would be different for each engine under consideration.

In connection with the Lee and Sparrow paper, with regard to the liability of burning the valves when using benzol as a fuel, it was stated that this effect had been found to be no worse than when using aviation gasoline. With reference to remarks made comparing constant-volume with constant-pressure engines, Mr. Lee stated that the efficiency is mainly dependent upon that of the air-cycle. Mention of the possibilities of the Diesel engine elicited numerous comments comparing Diesel-engine fuel-consumption with present-day automotive-engine results in this regard, expansion-ratios were discussed with reference to smooth running and the relative merits of thin and thick cylinders were accorded attention.

The foregoing sketch of the proceedings at the detonation session are only indicative; their complete presentation in an early issue of THE JOURNAL will be necessary before their full import can be comprehended.

RESEARCH PROMISES FUEL SAVING

Results of Society's Cooperation with Petroleum Industry Discussed

In the absence of Past-President J. G. Vincent, who was unable to be present, President B. B. Bachman presided at the Research Session of the Annual Meeting, which was held on the morning of Thursday, Jan. 11.

How the Research Was Organized

H. M. Crane, chairman of the Research Committee, confined his attention to the fuel activities of the Committee, in presenting the 1922 Report. Tracing the history of the Society's work on fuel for the past 3 years, Mr. Crane brought out the importance of the gradual rapprochement that has taken place between the petroleum producer and the automotive engineer, culminating in the undertaking of a joint research on the fuel problem 1 year ago. This concerted action had served, not only to clarify the issues involved, but also to insure the formation of rational conclusions.

The fuel research fell into two parts, one a program carried out last summer by the Bureau of Standards, a report of which appears elsewhere in this issue, and the other a program carried out by 10 companies in the Detroit district, working under the direction of the Research Department. Both tests covered a wide range of cars, typical of about 75 per cent of the total number in use in the Country, under a very considerable range of operating conditions. Mr. Crane explained that the problem under consideration had two phases, the question of the type of fuel that the operator would like to use if he could get it, and the question of what is the greatest departure from the theoretically best fuel that can be handled successfully in the present-day automobile.

The chief difference between the Bureau of Standards tests and those conducted by the companies was that the latter represented a somewhat more advanced product than was represented in the Bureau tests. In other words, many of the cars used in the companies' tests were of uptodate design.

The Results Summarized

The results of the tests indicated that in warm weather, purely from a mileage point of view, a fuel considerably worse than what is now being supplied would produce mileage almost in proportion to the quantity consumed. The company tests seemed to indicate less satisfactory results with the heavier than with the lighter fuels.

Mr. Crane reported the results of a test run made by another member of the Society, which showed that greater maximum-acceleration and car-mileage could be obtained with a fuel much lighter than commercial gasoline, by regulating the jacket-water temperature. The conclusion was that high volumetric-efficiency is incompatible with the best use of heavy fuels; that better results are obtainable with lighter than with heavier fuels in cars adapted to lighter fuels, but that in cars adapted to heavier fuels the use of the lighter ones gives no advantage. Crankcase-oil dilution is a sensitive index, but Mr. Crane declined to accept the presence of this phenomenon as evidence of the inadmissibility of any fuel.

R. E. Carlson's paper, which appears elsewhere in this issue, summarized the results and conclusions derived from the tests last summer of the four experimental fuels in four different models of car, which showed no significant difference in fuel mileage for the different fuels. He described also the results to date of experiments on a single engine mounted in a refrigerator chamber, the tests covering a wide range of operating temperatures. It is too early to draw definite conclusions from these tests. The series of cold tests will be supplemented by such road tests as appear necessary from the results obtained.

W. S. James continued the discussion of the project by explaining that the results so far obtained in the cold-chamber test cover a condition at the low-temperature end in which the fuel in the manifold must be mostly liquid, and at the high-temperature limit a condition of almost complete vaporization.

All of the four fuels may act alike when supplied to the engine as liquids, or as vapor, but differently when partially vaporized. The tests made so far may not cover the condition of partial vaporization, when maximum differences between the four fuels would become apparent. Mr. James illustrated this point by a sketch showing how the distribution of either a liquid or a vapor to the different cylinders may be uniform, while the distribution of a mixture of a liquid and a vapor may not be uniform. The Bureau will make further tests to clear up this point.

Ten Companies Cooperate in Service Tests

V. H. Gottschalk presented a report of the service fuel-tests run last summer by 10 companies in cooperation with the Research Department of the Society, using four fuels very similar to those used at the Bureau of Standards. In this series, 59 different passenger-cars of about 15 different models were run in ordinary service, each car running 1 week on each of the four fuels.

The results of these tests showed remarkable consistency in the mileages secured with the four fuels in all of the different models, the differences being not over 1.9 per cent on the average. Measurements of crankcase-oil dilution, however, showed a consistent increase from

the *A* fuel to the *D* fuel; with some of the cars the dilution with the *D* fuel was twice that with *B* or commercial-grade gasoline.

PETROLEUM INDUSTRY WELL REPRESENTED

Dr. Van H. Manning spoke on behalf of the petroleum industry. He emphasized the fact that cooperation between the two industries has resulted in the education of both. The oil industry will keep pace with the automotive industry in its development work.

T. J. Litle said that the important point in these tests is that the drivers do not like the *D* gasoline. We may be able to use it if necessary, but we would much prefer to use something better. In this connection he wished to know why the petroleum industry did not make more use of cracking processes.

F. A. Howard, replying to Mr. Litle, said that cracking in effect increases the supply of available crude but does not increase the percentage of good fuel. C. S. Kegerreis emphasized the difficulties in starting and in crankcase dilution experienced with the use of fuel *D* and considered that it would take time to adapt automotive equipment to its effective use.

In connection with the difficulty experienced in starting, O. C. Rohde stressed the importance of spark-gap setting. H. E. Pengilly suggested that the relatively better performance of the *B* or commercial-grade fuel was due to the fact that the manifolds, on the average, were heated to the temperature that suits this grade. He expressed the opinion that if the results were examined carefully it might appear that some of the cars were better adapted to make use of the heavier grades of fuel efficiently.

Herbert Chase asked if further data could be given on the types of car used in the tests by the 10 companies. Dr. Dickinson explained that more data were not given because some of the companies did not want their cars identified. He stated that a similar series of tests will be run by some or all of the same companies during winter weather.

AIR-COOLED PASSENGER CARS ADVOCATED

How Designers of Automobile Engines Can Benefit from Aircraft Practice

T. J. Litle, Jr., presided at the engine-cooling session held Jan. 12 as the closing feature of Annual Meeting week. He believes, as stated in his opening remarks, that the air-cooled passenger-car engine will be supreme, but that we do not know how to build it as yet. He expressed high appreciation of Mr. Heron's paper as another valuable contribution from the Government to automotive development, and said that automotive engineers often fail to realize how greatly the progress of the industry is assisted by such governmental agencies as the Air Service and the Bureau of Standards, in view of the research data that the Government makes available from time to time in the published reports of these organizations.

The paper by S. D. Heron on Aircraft-Engine Practice as Applied to Air-Cooled Passenger-Car Engines, which was printed in the January, 1923, issue of THE JOURNAL, was presented by the author briefly, in abstract form, with running comment on the actual text. He stated that most of the copying of aircraft practice in postwar car-design had proved a failure because the fundamental difference in duty had not been realized, and proposed to show wherein the automobile designer and the engine builder can profit by the use of the practice developed for air-cooled aircraft-engines. After generalizing on the main considerations involved, he gave an exposition of the simplicity of layout of the efficient air-cooled cylinder, as a preface to a somewhat detailed discussion regarding cylinder design and performance, inclusive of valve location, types of finning and the form of the cylinder-head.

Cylinder material, cooling surface, port-arrangement for in-line engines and the camshaft and valve-gear arrangement most desirable were treated at length and illustrated. A consideration of sleeve-valve types, temperature and exhaust-valve cooling followed, accompanied by many enlightening data. Similar treatment was accorded the subjects of air supply, a cooling system for in-line engines, air-blast direction and the necessary quantity of air.

The desirable types of fan, spark-plug, piston and fuel were commented upon somewhat briefly. Mr. Heron concluded that (*a*) the scaling-down of design in internal-combustion-engine cylinders is a safe process, while scaling-up is decidedly unsound; and that (*b*), since thermal troubles have been the greatest cause of difficulty with air-cooled cars, a consideration of the designs capable of full-throttle operation is likely to demonstrate the ease with which the relatively mild thermal efficiencies of an air-cooled car can be overcome.

The two appendices to this paper, by C. Fayette Taylor and E. H. Dix, Jr., respectively, related to the experimental development of air-cooled engine-cylinders and the foundry production of air-cooled cylinders having the fins cast integrally.

RADIATOR CAPACITIES FOR COOLING

Heat-Dissipating Properties of Three Types of Radiator Core

The last paper of the session devoted to engine cooling was presented by Prof. E. H. Lockwood and gave the results of an investigation made at the Mason Laboratory, Yale University. Its title is the Cooling Capacity of Automobile Radiators. It was published in the January, 1923, issue of THE JOURNAL.

The three types of core investigated include the fin-and-tube, the ribbon and the air-tube groups, classified thus according to the flow of the water and the air. The ratios of the cooling surface to the volume are shown to be nearly the same in the fin-and-tube and the air-tube cores; in the ribbon core the ratio is somewhat greater.

Professor Lockwood derived a formula for computing the heat-transfer coefficient, which is defined as the number of heat units per hour that will pass from one square foot of surface per degree of temperature-difference between the air and the water. This coefficient is the key to ascertaining radiator performance; by the use of it, almost any desired information can be obtained.

When the heat-transfer coefficients have been found for a sufficiently wide range of water-flows and air-flows, the cooling capacity of a radiator can be computed for any desired condition. Five fundamental formulas were given, together with six derived formulas, the mathematics involved being given in an appendix.

The formulas cover topics such as pump circulation, thermo-syphon circulation, the limiting depth of core required, final temperatures, weight of water-flow and the like. The results of applying the formulas to six cores that were selected as representative of the three main types of radiator construction were illustrated by a series of charts.

ENGINE COOLING FROM VARIOUS ANGLES

An Indication of the Trend of Thought Regarding Cooling Systems

Various phases of the subject were discussed after the presentation of the papers at the session devoted to engine cooling. The subject of cooling by the auxiliary use of steam was treated. Some further information regarding the practical use of the Lockwood formulas for radiator calculations was presented.

S. D. Heron demonstrated a working model of a pattern for use in casting an air-cooled cylinder, explained the foundry process and exhibited other patterns for some of the cylinders illustrated in his paper.

L. H. Pomeroy doubted the success of the air-cooled engine for high-class passenger-car service, because of factors that tend to make it noisy. He believed that the chief source of noise lies in the variations of temperature and also that the control of vibration is influenced by the temperature differences. Further, that if high internal friction is a characteristic of an air-cooled engine, it is not a satisfactory powerplant.

C. P. Grimes presented interesting comment on the performance of the well-known air-cooled car he represents, together with remarks on cylinder cooling-fins, fans and the starting of cold engines.

H. S. McDewell expressed the opinion that the air-cooled engine would now have the advantage, if the same amount and quality of research work and development had been applied to it as have been expended upon the water-cooled engine. He believes that engine designers are not in close enough touch with aircraft-engine practice. He called attention to the fact that air and water-cooled engines are both cooled also *by oil*, and that this factor should not be neglected. His view concerning the scaling-down of engines as being safe, and the scaling-up being decidedly unsound, coincides with that expressed by Mr. Heron.

Thomas Midgley, Jr., gave an outline of the benefit obtained by using copper as a surface for cooling.

C. Lawrance made remarks concerning internal engine-friction and stated that it is always desirable to remove heat first from the point nearest its source. He believed that successful air-cooled engines can be produced in sizes that are suitable for automotive usage.

Dr. H. C. Dickinson mentioned the desirability of maintaining uniformity of the cylinder temperature, Chairman Litle spoke of having seen red-hot valves on a water-cooled engine and Mr. Grimes stated that the temperature of an engine cylinder is not related to the economy of an engine.

Mr. Heron, in conclusion, commented briefly upon the various questions. He mentioned factors that tend to produce silent engine-running, and discussed temperature control of the air-cooled engine. He thought that fins cast integrally with the cylinder are most successful.

MOTORBOAT ENGINEERS MEET

J. G. Vincent to Present Paper at Motorboat Meeting on Feb. 28

The annual Motorboat Meeting of the Society will be held at the Hotel Commodore, New York City, Feb. 28, at 10 o'clock. The date selected occurs during the week of the National Motorboat Show in New York City. A group of papers on motorboat subjects will be read and discussed in the meeting, and an informal lunch will follow at 1 o'clock.

J. G. Vincent, vice-president of the Packard Motor Car Co., will read a paper on Modern Tendencies in High-Speed Motorboat Engine Design. Mr. Vincent's success in winning the Gold Cup Trophy with his "Packard Chriscraft" and his standing as a designer of aircraft and automobile engines, assure the members of an interesting and informative paper. Efforts are being made to secure a paper on Diesel engines for yachts and a brief talk by a motorboat owner on the improvements in motorboat engines that the owner considers desirable from his standpoint.

Final details of the program for this meeting will reach the members in the *Meetings Bulletin* about Feb. 15.

ANNUAL MEETING IN DETROIT

Decision Made to Locate It in the Middle West in 1924

The next Annual Meeting of the Society will be held in Detroit in January, 1924, probably during the week preceding the Chicago Show. This recommendation of the 1923 Meetings Committee was approved at the first session of the new Council of the Society last month. Such a distinct departure from past precedent has not been made without careful study and sufficient reason. The demand for a change in the time and the location of the Annual Meeting has grown with each succeeding year, and now it is believed good judgment to alter precedent for the best interests of the Society.

It has been the belief in the past that holding the Annual Meeting coincident with the national automobile show in New York City resulted in a larger and more representative attendance. Some have argued that without the dual attraction the meeting could not be successful. This argument is disproved by the success of the Production Meeting in Detroit where, with the meeting as the sole attraction, technical sessions were attended by the largest audiences ever attending Society meetings, and nearly 500 were seated at the dinner. When programs are attractive, subjects timely, speakers are authorities and distances not too great, members will be drawn to Society meetings in satisfactory numbers.

Show Week Unsatisfactory Time

Probably the strongest argument against the New York City meeting has been its conflict with other matters of greater urgency to members attending the show. Every visitor to New York City feels in duty bound to make a careful study of the exhibits at the show. This is impractical in the evenings because of the crowds, and must be done during the day in conflict with Society meetings. Organization, dealer and sales luncheons and business meetings are other conflicting events. Many members find it altogether impossible to leave the headquarters of their companies for any appreciable time during the show period. Evenings are crammed with business and social activities that make one reluctant about arising early and attending professional sessions. It seems nearly impossible to get meetings started on time during show week; in Detroit, where the meeting was the sole attraction, sessions started promptly with a satisfactory audience in point of numbers.

The New York Show always attracts the major executives from the factories with the natural result that many engineers and production men in minor capacities must remain at home. A meeting arranged at any other

period would probably find these younger men able to leave their work. With a location more nearly in the center of production, travel expense of the younger men will be decreased, and they are more apt to attend the meetings. The Annual Meeting is considered generally as the most representative meeting held by the Society during the year; the attendance of the younger men who are destined to carry on the future work of the Society, is highly desirable for this reason.

Summer Meeting Location a Factor

The Meetings Committee has met an extremely difficult problem in the selection of a suitable place for the Summer Meeting of the Society. It seems to be the general opinion that most of the popular resorts suited to our peculiar requirements lie in the Eastern region. It has always been the custom to hold the Summer Meeting in the Middle West and the Winter Meeting in the East. A change in this practice will overcome the Show Week handicaps just enumerated, and place the Summer Meeting in a district that includes many splendid resorts with adequate hotel and recreational facilities. This move seemed logical, and was an important factor in locating the Winter Meeting in the Middle West.

Annual Dinner Remains in New York

The Annual Dinner of the Society will continue to be held in New York City on Thursday evening of Show Week. This dinner has become recognized as an institution; it continues to attract the industry's most representative men, and there has been no suggestion of discontinuing it or changing its time or location. The annual sessions of the Standards Committee will also continue to be held in New York City at show time. This practice makes it possible to either shorten the Annual Meeting period or devote another day to technical matters in Detroit. It also allows a longer period before the Summer Meeting for the formulation of new standards and recommended practices.

NATIONAL TRACTOR MEETING

Chairman Rumney of the Meetings Committee has appointed H. O. K. Meister chairman of a special committee that will arrange a National Tractor Meeting of the Society sometime during the spring. The location and date of the meeting will be selected to coincide with some national tractor activity, such as a demonstration or show, enabling a large number of tractor men to attend. Any suggestions or offers of cooperation in the arrangement of the Tractor Meeting should be addressed to the New York office.

AUTOMOTIVE TRANSPORT MEETING

Truck, Bus, Taxicab and Rail-Car to Be Treated at Cleveland Meeting

A National meeting of the Society devoted to commercial automotive transportation will be held at Cleveland some time in April. Although the date of the meeting has not been set, the plan of the technical activities has been defined. There will be at least four engineering sessions devoted respectively to truck, motorbus, taxicab and motor rail-car transportation. Operation rather than design will be featured in the truck and motorbus meetings. The taxicab session will include papers on both design and operation. Representative motive power engineers of railroads that have experimented with rail-cars, are being asked to contribute their experience to the rail-car meeting.

The preliminary arrangements for the Cleveland Transportation Meeting are in charge of a sub-committee of the Meetings Committee headed by A. J. Scaife. Requests for representation on the program should be addressed to the Society headquarters in New York City. Progress in the arrangements will be recorded in future issues of The Journal and the *Meetings Bulletin.*

1923 PRODUCTION MEETING

Factory Problems Subject of National Meeting in Cleveland Next October

The Meetings Committee announces that the 1923 Production Meeting will be held at Cleveland during October of this year. This is in accordance with the plan in mind when the Detroit Production Meeting was arranged, that is, the meeting site will be changed from year to year, but will be located in the region where the major portion of automotive parts and vehicles are produced.

Papers for the 1923 Production Meeting are being solicited at the present time. Perhaps you have a subject in mind for discussion at this meeting; or, better still, you may wish to present a paper. Write to the New York office of the Society and submit your suggestions. Papers on new processes, shop methods or production research are welcomed. We require timely papers on factory economics, wage systems, planning, purchasing and allied subjects. Selection of papers will be on a competitive basis, the papers of greatest practical value being given places on the program. The committee hopes even to surpass the unusually successful Detroit meeting, and asks the earnest cooperation of every man engaged in the producing branch of the industry.

INDUCTOR MAGNETO ADVANTAGES

Engineer Outlines Them at Section Meeting in Boston

M. E. Toepel, electrical engineer with the International Motor Co., addressed the members of the New England Section at their meeting on Jan. 18 in Boston. He described recent developments in the polar-inductor type of magneto, stating that this type had greater possibilities than either the rotating armature or the shuttle type. Important magneto parts can be replaced more easily in the polar-inductor magneto, spark characteristics can be changed to suit any individual requirement and it is possible to have all sparks of the same polarity. There are two important disadvantages met with in polar-inductor magnetos; losses in magnetic flux transmission to the core of the winding and loss of efficiency when the relation between the magnetic and the mechanical break is altered by the wear of the actuating parts. Mr. Toepel made a plea for better weatherproofing of magnetos, referring particularly to accomplishing this within the magneto rather than by providing special covers, gaskets and the like.

A high-speed engine with positively operated valves will be described by Rollin Abell at the meeting of the New England Section to be held, Feb. 15. A single poppet valve is used in each cylinder of this engine, this being put in communication alternately with inlet and exhaust-ports by a rotary distributor valve placed lengthwise of the cylinder-head. It is claimed that the trapping of a small charge of exhaust gas at the end of each

exhaust stroke and the dilution of the incoming charge with this exhaust gas, makes it possible to use high compression without any resultant detonation. The meeting will be held at the Buckminster Hotel, starting at 8 o'clock, and all members and their friends are invited to hear Mr. Abell's interesting paper.

KETTERING FAVORS RESEARCH

Surest Means of Avoiding Crystallization and the Saturation Point

C. F. Kettering was in particularly good form when he addressed the Buffalo Section members at their annual dinner, Jan. 18. He based his talk on a heading he had noticed in an advertisement in one of the weekly magazines, "Search for Spices Led Columbus to Discover America." The determination to accomplish a specific purpose led Columbus to make a far greater and more important discovery. Mr. Kettering stated that a similar result was often encountered in physical research. It was with the purpose of finding a satisfactory method of burning kerosene in internal-combustion engines that the members of Mr. Kettering's research staff were led through a long series of experiments to the fundamental causes of detonation and the discovery of anti-knocking dopes. Mr. Kettering recommended that all research be started with a definite purpose in mind, but we must not be surprised if our course leads to discoveries that were not anticipated.

The research man must be continually asking, "Why?" He must not accept everything as being fundamentally correct in its present state. His viewpoint must be a constantly changing one. He must not settle down to the state where he feels that everything is satisfactory; he must ask himself, "Why do I do this thing this way?" The fact that a thing has never been done must not discourage him in attacking a problem. He must set upon the problem as it exists and determine why it has never been solved.

As an illustration of the viewpoint a research man must take, Mr. Kettering quoted a recent experience he had had with automobile painting. He asked his men this question: "Why not paint an automobile body in 1 hr. instead of 30 days?" The question appears ridiculous until it is realized that the research man immediately perceives that he must attack the painting problem in an entirely new way if he is to make a satisfactory investigation. He immediately realizes that such a saving of time cannot be accomplished with the present methods and materials. This particular investigation did not lead to the discovery of a method of painting automobiles in 1 hr., but it did lead to a surprisingly productive piece of research, as a result of which the time taken to paint an automobile at present will be materially reduced.

It is Mr. Kettering's belief that research and continuous development will be the salvation of the automotive industry. The oft-anticipated point of saturation will not be reached so long as each new crop of automobiles represents a material engineering advance over those of the previous year. We must not let the automotive industry crystallize; we must not accept our present automobiles as satisfactory. It is Mr. Kettering's belief that there is plenty of opportunity for the further development of the present-day automobile. He cited tire-changing and ill-fitting side curtains as two examples of items that are far from the ideal. We must continue to build automobiles of the finest material and with the best workmanship, but improvement must be rapid, so that the new models shall be attractive enough to the owner to make him anxious to part with his old car. Automobile design must and will change in the next five years because of public demand and a continuing incorporation of the results of scientific investigation into the finished product.

Charles L. Sheppy acted as toastmaster of the dinner. The speaking program was followed by a most enjoyable program of entertainment, all the talent being members of the Buffalo Section. Otto M. Burkhardt and the members of his Dinner Committee are to be congratulated on the success of the dinner and the enthusiasm it will undoubtedly arouse among the Buffalo members of the Society.

RADIO BROADCAST SUCCESSFUL

A group of letters received from enthusiastic radio listeners throughout the country is evidence of the success of the radio broadcasting of the Annual Dinner of the Society in New York City. Letters have been received from points as far distant as La Crosse, Wis., Quebec, Canada, Anderson, Ind., Augusta, Me., and Ashland, Ohio. Members of Mr. Kettering's family at his home in Ohio heard his remarks as toastmaster.

The success of this innovation will result undoubtedly in the broadcasting of future programs of the Society. Papers at the technical sessions are not suitable for broadcasting because of their usual complexity and lack

Schedule of Sections Meetings

FEBRUARY

2—Detroit Section—Production Meeting—The Organization of Motor-Car Construction from Layout to the Finished Car—L. V. Cram, H. W. Hayes and others
2—Washington Section—Research in Aeronautics—George W. Lewis; Recent Developments in Aircraft Power-plants in the Navy—Lieut. B. G. Leighton, U. S. N.
7—Minneapolis Section—Transportation on the Upper Mississippi River via Barge, Motor Tow-Boat and Terminal Delivery by Truck—J. S. Brodie
8—Indiana Section—Practical Application of Lubricants—W. F. Parish
8—Metropolitan Section—Joint meeting with Automotive Service Association—Relation of the Service Station to the Factory and Engineering Dept.—Speakers, J. W. Lord and B. B. Bachman
15—New England Section—A High-Speed Engine with Unconventional Valve-Gear—Rollin Abell
20—Dayton Section—Alloy-Steel Valves and the Effect of Heat on Various Steel-Alloys—Robert Jardine
21—Pennsylvania Section—Lubrication Meeting
23—Buffalo Section—The Manufacture of Wire Wheels—W. W. Davison; The Future of the Steel Disc Wheel—J. W. White

of appeal to the general class of radio listeners. The radio broadcasting stations have shown an interest in popular talks, however, and those Society programs that appeal to the public will probably be carried via air to our members in the future.

FEATURE PRODUCTION MEETINGS

Detroit Section to Devote Series of Meetings to Factory Problems

The Detroit Section intends to devote all of its meetings during the remainder of the Section year to matters closely related to the producing arm of the industry. It is the intention to discuss jointly the engineering and the shop phase of each problem with the commendable object of bringing designing and producing men into closer relationship. Interest in the meetings is being stimulated among factory men and a large attendance seems assured.

The first meeting of the series is scheduled for the evening of Feb. 2 at the General Motors Building on the Grand Boulevard. The Section will hold all of its meetings at this new location in the future. L. V. Cram of the Chevrolet Motor Co., H. W. Hayes of Dodge Bros. and representatives of the Ford and Studebaker production divisions will address the meeting. They will speak on consecutive steps in the Organization of Motor-Car Construction from the Layout to the Finished Car. The meeting starts at 8 o'clock and will be preceded by an informal supper at 6:30 p. m.

MID-WEST SECTION LUNCHEON

The Mid-West Section held an informal luncheon in Chicago, Jan. 16, for the purpose of selecting a nominating committee whose duty it will be to select a ticket of officers for the next Section year. The committee consists of B. S. Pfeiffer, W. O. Olson, F. H. Ford, W. L. Kaiser and H. E. Kirby. Reports were made by several committees, that on membership showing that the Mid-West Section has 132 members in good standing. Plans for Mid-West Section activity at the summer meeting were discussed.

GUERNSEY TALKS ON RAIL-CARS

Tells Cleveland Section That Demand for Them is Limited

Charles O. Guernsey addressed the Cleveland Section of the Society on Jan. 19 with particular reference to the self-contained railroad car. Mr. Guernsey confirmed the remarks of Elisha Lee, vice-president of the Pennsylvania Railroad Co., whose address at the Annual Dinner of the Society is printed in this issue of THE JOURNAL. He stated that the railroads require a vehicle that will carry approximately 80 passengers at a speed up to 40 m.p.h. and is capable also of carrying a proportionate amount of baggage.

Mr. Guernsey touched on the possible market for such a vehicle and it was somewhat surprising to learn that some estimates placed this as low as 1500, the highest estimate being about 7000 units. In the course of the discussion, which was very animated, several speakers took exception to this figure and thought that possibly this was the usual under-estimate of a new proposition. It was brought out in the discussion, that the expected life of a motor rail-car was about 12 years. This would require a probable production of between 300 and 400 per year. Mr. Guernsey pointed out that the situation was further complicated by every railroad insisting upon its own specifications with the result that practically every vehicle was a problem in itself. The automotive engineers' work on the rail-car is bringing the advantages of alloy-steels and anti-friction bearings forcibly to the attention of the railroad people.

MOTORBUS CHASSIS MUST BE SPECIAL

Service Conditions Demand a Vehicle Suitably Designed to Meet Them

The time is past when any good motor-truck chassis equipped with a bus body is a satisfactory public conveyance, in the opinion of H. L. Bollum, president of the Twin City Motor Bus Co. of Minneapolis. Mr. Bollum addressed the Minneapolis Section of the Society on the evening of Jan. 3. The trend of motorbus design is toward longer wheelbases, wider frames and a lower center of gravity. It is not reasonable to suppose that any chassis can be built so that it will meet the requirements of all operating conditions. Different motorbus chassis will be needed just the same as truck operators require trucks of differing capacity. Mr. Bollum felt that there will be as much difference between the different types required as there is between a touring car and a heavy truck.

It is generally agreed that the fundamentals of good motorbus design are stability and easy riding; touring-car ability with motor-truck stamina is wanted. Strength is essential not only for durability but also for safety. Ease of handling is another important factor since the average driver is capable of only a given amount of work and the easier his bus steers and handles, the more mileage he can cover in a day's work. Ease of operation also lessens accident hazards.

Mr. Bollum is an advocate of the unit repair system where any unit such as an engine or rear axle can be taken out and replaced from stock with another unit. Under this system, the worn part can be repaired without unnecessary delay to the whole motorbus.

The driver is the largest contributing factor to successful motorbus operation, in Mr. Bollum's opinion. Upon his ability, enthusiasm and loyalty to his employer depends the difference between excessive and nominal operating costs. His actions have a direct bearing on every item of expense. He must be a chauffeur, mechanician, conductor and ticket agent all in one. He is the medium of contact between the public and the company. Upon him rests the responsibility of maintaining his schedule, collecting all the fares and acting as a general information bureau. His employer expects him to look neat and clean despite the fact that he must change tires and make roadside repairs and adjustments occasionally. He must know his place and not be presumptuous, at the same time tactfully informing passengers that he cannot carry on a conversation and drive a motorbus at the same time.

M. O. Moeller presented a well prepared paper on the Mechanical Requirements of Bus Service. He took up each unit in the motorbus chassis and explained the special design considerations that must be kept in mind when building a satisfactory motorbus chassis.

The next meeting of the Minneapolis Section will be held on Feb. 7 and will be addressed by J. F. Brodie. Transportation on the upper Mississippi will be outlined

giving the present possibilities for river transportation in coordination with motor transport. Mr. Brodie will discuss operations by motor tow-boat comparing gas and heavy oil engines and screw propulsion as opposed to paddle wheels. Terminal facilities will be touched upon as well as the delivery and collection of freight by motor truck. Minneapolis Section meetings are held at the Builders Exchange and start at 8 o'clock.

TRUCKS CANNOT SUPPLANT RAILROADS

Motor Transport Officer Presents Army's Emergency Control Plan at Washington

Motor transportation can never, either in an emergency or in daily commercial practice, replace the long-haul railroad service in this Country. This is the belief of Major Brainerd Taylor of the Quartermaster Department of the United States Army who addressed the Washington Section of the Society on the evening of Jan. 5. Major Taylor was detailed to represent the Army highway transport engineers in preparing a plan for relieving the emergency during the railroad strike of 1922. He presented the details of this plan at the Washington Section meeting showing a map and a manual prepared by the Motor Transport Corps for use by civilian and Army truck organizations.

Major Taylor said that the intense school of highway transportation in France during the war was the best school in which a highway transport engineer could possibly have received his education. The field of practical highway transportation in the American Expeditionary Force was more valuable to commerce than any field of transportation that commerce itself has developed so far. The highway transport engineer is still a new and much doubted individual. If there were more of them we would not hear so much about "Ship by Truck" but would hear more about "Ship by Highway Transport." The automobile industry would not be selling trucks, it would sell fleets of trucks. The railroads would not be talking about taxing the truck operator for the use of highways to make competition fair, for they would be the greatest beneficiary from a highway transport service that radiated from their terminals.

In the emergency plan described by Major Taylor, coordination of motor transportation with rail and water transportation and highway traffic control are exercised from the offices of motor transport centers by chief dispatchers, through truck dispatchers who are located at garages and cargo-spotters who are located at railroad and waterway stops and terminals. The truck equipment at each of the motor transport centers bears a direct relation to the amount of city and country freight collected and distributed from railroads and waterway terminals in that district.

The maintenance of motor vehicles in the system is organized and centralized to effect the greatest efficiency. Light repairs are made in garages under the supervision of truck-center administrative officers. Major repairs, overhaul and salvage are conducted at central shops and depots. Service and fuel stations are connected by telephone through the offices of the chief dispatcher to facilitate timely service and to supply information for the control of the entire system.

A paper on the Engineering Aspects of Traffic was read by W. P. Eno in which he called attention to some of the material on the control of traffic that has been published under his direction. He stated that he was not in favor of the present plan of regulating traffic by towers as employed on Fifth Avenue in New York City. He favored the rotary system of traffic control at congested centers and cited the arrangement at Columbus Circle in New York City as an outstanding example of the success of this method. The papers were followed by a very active discussion of specific examples of traffic congestion in some of the larger cities.

The next meeting of the Washington Section will be held on Feb. 2 at the Cosmos Club Lecture Hall starting at 8 o'clock. George W. Lewis, executive officer of the National Advisory Committee for Aeronautics, will speak on Research in Aeronautics. His lecture will be illustrated with lantern slides and motion pictures, the latter showing the recent glider competition in France. A second paper will be presented by Lieut. B. G. Leighton who is in charge of the aeronautic engine development of the Navy. The title of his paper will be Recent Developments in Aircraft Powerplants in the Navy. It will include a resume of the lessons learned from the recent Pulitzer Race and the result of the Navy's adoption of a 300-hr. test for aircraft engines and its effect on recent engine design. He will also touch on the Navy's experience with special fuels for high-compression engines.

DETERMINING VARNISH QUALITIES

Demonstration of Laboratory Procedure Supplements Presentation of Paper

The first body engineering session was held on the afternoon of Tuesday, Jan. 9, George W. Kerr presiding. Papers on Automobile Finishing-Varnish, by L. Valentine Pulsifer, and on the Needless Hardwood Lumber Waste, by Frederick F. Murray, furnished the material for discussion.

Mr. Pulsifer's paper was accompanied by a demonstration of laboratory tests. After explaining the various qualities that are included under the terms shop qualities and service qualities, with the aid of members of his staff he showed how they might be determined experimentally. First showing how two varnishes might be compared with regard to their working, flowing and setting abilities, tests then were made to indicate how the viscosity, elasticity, moisture and alkali resistance, film-factor and service-durability rating were ascertained. The Kauri reduction-test for determining the gum-oil ratio upon which the elasticity of the varnish depends was described in detail.

Replying to a question of S. G. Tilden in the discussion of the paper, Mr. Pulsifer said that body polishes not only do not increase the life of a varnish but frequently contain abrasive material that is destructive. Waxing increases the varnish, but to put on a new finish the old surface must first be removed. Chairman Kerr brought out the point that a certain amount of moisture in the drying room is desirable to avoid too rapid setting of the varnish, usually a difference of about 20 deg. between the wet and dry bulbs of the thermometer; with enforced drying this might reach 80 or 90. In answer to F. E. McCleary, Mr. Pulsifer stated that on account of the number of variables the use of the violet ray thus far was only experimental. Answering Herbert Chase, he said it was possible to produce a durable finish that is not lustrous, but that by adding an excessive amount of pigment and by rubbing-down a varnish such as a chassis varnish it might be brought to a dull finish, the durability would depend on the quality of the materials used. To another query of Mr. McCleary, he re-

plied that toughness rather than hardness determines the resistance to abrasion. The results of too quick drying and too great hardness are too little understood; the durability would be doubled if more time were allowed in the application of the varnish. In replying to Mr. Shidle, Mr. Pulsifer said that price does not follow the rating of the varnish on the durability-rating chart. Comparing varnishes *D* and *A* on the chart, the ratio of durability is 6 to 1, whereas the price-ratio is about 2 to 1. To Mr. Kerr's point regarding rust he replied that rusting under the varnish is due to insufficient cleaning and to rust that has not been removed before the primer was applied. To Mr. Kendall's question, Mr. Pulsifer stated that distilled water has more effect in turning varnish white than has salt water. Although salt acts as an abrasive, it is the dew and fog that cause the most damage on ships.

SIMPLIFIED HARDWOOD SPECIFICATIONS

Revision of Existing Obsolete Grading Methods Urged to Prevent Waste

Mr. Murray by lantern-slides showed the process of obtaining hardwood lumber, following its course from the cutting of the tree to the finished product. The views included the felling of ash, oak and gum trees; the manner of transporting the logs to the sawmills by oxen, mules, tractors and steam trains; the methods of handling the logs at the mill; quartersawing; cutting veneer; and loading the lumber on the cars. The only way, he said, in which to get lumber into its proper classification is by grade specifications. Grade structures were written before the automotive industry came into existence. No. 1 top grade is composed of firsts and seconds, but there are not enough firsts and seconds to go round. Grades, therefore, must be drawn in terms of certain cut-up sizes. Specifications are written in terms of secondary defects but without regard to how the defects appear in the board. The idea that a board with two defects is only one-half as valuable as a board with only one defect is erroneous. But a No. 2 board is very desirable, while a No. 3 board is suitable for toys, and so on. By defining boards in terms of the cut-up sizes 15 or 20 per cent can be saved; and 5 per cent would be worthwhile, because of the diminishing supply and the increasing demand. The specifications should take a certain cut as a minimum and increase 1 in. at a time up to a maximum of 96 in. The question resolves itself into a tabulation of cut-up sizes. A special committee should classify cars and in the classification include the various makes and body styles, so that the committee could supply a list that would represent the automotive field. In the tabulation of the cut there will be shown a remarkable standardization of size. Getting the data is a greater task than reviewing the requirements, and the proper way of doing so would have to be worked-out. The American specifications are the greatest movement ever sponsored by the Department of Commerce. A good plan to conserve hardwood would be for Congress to prohibit the shipping of lumber except to automotive and farm implement industries, and not to the building trades. In Memphis a movement started to use 2x4-in pieces for building, to secure a better market, as more defects are allowed. The producers also look to the railroads to use the gum tie. By treating the ties immediately after being cut the incipient stages of decay are controlled and the mechanical wear and resistance to rot are increased.

CUTTING CLOSED-BODY PRODUCTION COSTS

Wire Mesh, Buckram and Leather Substitutes Utilized Instead of Sheet Metal

At the second body engineering session, held on Wednesday, Jan. 10, with G. E. Goddard presiding, the papers were by George J. Mercer, on Cheaper Closed-Body Construction, and by J. B. Davis, on the Testing of Leather Substitutes and Top Material.

Mr. Mercer called attention to the fact that the estimated output of closed cars for 1922 is 635,000, which is about double that of 1921 and nearly three times that of 1919; and that the ratio of closed to open bodies is constantly increasing. Commencing with the all-wood body similar to that of a carriage, first aluminum and later sheet-steel were substituted for the panels, then the all-steel body was introduced. The last named has the advantage that when assembled it can be bake-enameled, which increases the durability and saves time. But this necessitates the continuing of one model for a long time and also limits the finish to black. Other methods of reducing the cost of production include smaller bodies of simpler design with straighter lines and rounded corners, fewer moldings, duplicate glass-sizes, simpler door-hinges and trimmings, fabric roofs and improved painting methods. A recent effort at reducing the cost is by constructing the body in sections and shipping it in the knockdown shape. A radical innovation is the covering of the body entirely with fabric over a foundation of wire and buckram which is fastened to the conventional wood framing.

To those who are familiar with the California top the idea is not new and the durability is well known. The fabric body has the advantage of using a foundation that is cheaper, lighter, more easily and quickly applied, yet is of sufficient rigidity to retain its shape when molded. In appearance it is said to resemble the landau leather that has always added a satisfying finish to high-priced cars. Two years of service in all kinds of weather has shown the finish to have lasting qualities and brightening it requires nothing more than the friction of a soft cloth; its elasticity is sufficient to absorb shocks, while at the same time its non-conductance of heat renders it warm in winter and cool in summer. The weight is said to be ¾ lb. per sq. ft. as compared with ⅞ lb. for aluminum and 1½ lb. for steel. The flat cost of the covering and the foundation material on the sample body described in the paper was 26 cents per sq. ft. Aluminum costs 30 cents per sq. ft. and steel 7 cents, not including the stamping and hammer costs as well as the finishing and painting. The work of designing, millwork and framing is the same as for an ordinary body but a great saving is to be made in finishing; two men finished both the interior and exterior of a car in 2 weeks. No such care was required to protect the outer surface, which was finished first, as would have been necessary had the surface been painted. Even when shipped the body was not covered. As enameling is a quicker operation than painting, the fabric-covered body will effect a saving in time of from 5 to 11 days according to the quality of the work considered. Imitation leather, more properly called leather-cloth, heretofore has been made only with a semi-dull finish, but the high luster of the new process offers an additional attractive feature. Summing up, the actual benefits to be derived from a fabric-covered body are that it is of lighter weight, is more quickly fabricated, is

sound-proof and suitable for all seasons, has unequalled flexibility of construction that will allow the more expensive shapes to be made cheaply, and at the same time possesses a finish, design and attractiveness comparable to bodies made with the customary materials.

About 80 persons were present during the reading of Mr. Mercer's paper and the interest that it aroused was indicated by a lively discussion which was taken part in by Messrs. E. W. M. Bailey, Chairman Goddard, G. W. Kerr, L. C. Hill, Edward Wotton, P. W. Steinbeck, Alvin Hunsicker, H. B. Day and L. L. Williams. Replying to questions, Mr. Mercer explained that the forming of the wire on the body was done by hand and that the upper round back-corner, which was expected to give trouble, was found to be surprisingly easy. Usually, he said, it would be better to put the buckram on a form and let it dry before installing it, especially in mass production. Regarding the necessity of making the wood-frame structure stronger at the joints than when metal panels are used, he had decided that it would make no difference except, possibly, in special cases.

Three-point engine suspension gives greater flexibility of the chassis but has a tendency to distort the frame; the fabric construction would make the body more uniformly flexible rather than localize this distortion. The tendency of leather to stretch and sag is not apparent in leather cloth on account of its being stretched and shrunk in much the same manner as paper on a drafting-board. Two years of hard service has failed to show any deterioration. Mr. Warren emphasized the difference between the construction of a passenger car and a motor-coach, the latter requiring much greater strength and stiffness on account of the greater width between the supports, but if the coach were to run on pneumatic tires at a high rate of speed such as might be demanded on interurban service the question of flexibility would be important. With regard to possible bulging between the moldings and on the sidesweeps and turn-under, no trouble was experienced as the material is fastened under the molding before the molding is applied. The surface of the leather cloth is not soft and flexible but it is stretched tightly over a firm foundation. No wadding is required because the surface is built full before the material is put on. With regard to the patent aspect Mr. Mercer's understanding was that there would be no restrictive methods used to prevent any body-builder from availing himself of this form of construction but that Mr. Childs would undoubtedly protect himself in some way and endeavor to reimburse himself for the money he had spent in conducting 2½ years of experimental work.

Chairman Goddard believed the all-steel body would come eventually, because when produced in a sufficient quantity the cost is less; it can be pressed out of the sheet, electrically welded, assembled and enameled in somewhat over a day of actual time, whereas a wooden sedan body requires about 106 days, including 18 or 19 for painting. To demonstrate whether a stiffer frame will be required to prevent the joints loosening up in service a test car will be put on the road in February and tried out on hard roads in bad weather. Patching can be made as easily as with wood or metal panels. If the modern method of building were used, replacing a section would be easier than repairing.

The use of fabric panels in buses was said by Mr. Wotten to be adequate for anything short of a collision, but that excessive distortion would have to be taken care of by additional braces.

To E. W. M. Bailey's question, Mr. Mercer replied that the elasticity of the fabric appeared to be one of its most attractive features, for every closed body must twist; the frame instead of being made heavier should be made lighter with heavier joints. G. W. Kerr stated that he had made experiments in which a chassis had been twisted 1½ in. He believed the tendency was in the direction of the unbendable and untwistable frame. Even with the stiffest bodies the glass frequently breaks because of a sudden twist. He thought that sagging was caused not by stretching but by shrinking. Leather tops on carriages always used to shrink. The soft roof has proved satisfactory in deadening sound. In the old days the green hide was stretched over the roof and down the sides and the back; it was then painted, rough-stuffed, varnished and finished, as if it were wood. Alvin Hunsicker compared the fabric to that of which a Van Heusen collar is made, two fabrics being constructed in a different way and put together with waterproof cement, so that they cannot stretch. Referring to Mr. Kerr's remarks on the stiffness of the chassis, Chairman Goddard remarked that there was no doubt that the frame was becoming stiffer. There should be no spring in the frame; all the flexibility should be in the springs. These are usually made to carry correctly three-quarters of the passenger load; that is, a five-passenger body will ride under average conditions with three and one-half to four passengers. A check that he had made, which was confirmed by E. S. Jordan, showed that during a period of 6 months, as observed on street corners, the average number of passengers carried per car was 1.6. He noted that the Hotchkiss frame referred to by Mr. Kerr not only had cross bracing but was built much heavier than was necessary and that the intersection of the four members of the cross was drilled with holes, evidently for the purpose of mounting a gun. L. C. Hill called attention to the recent canvass of the National Automobile Chamber of Commerce which showed that 60 per cent of the users of cars want closed and 40 per cent want open bodies; methods of cutting down the cost of closed bodies, therefore, should be considered.

Mr. Mercer, replying to a question on the proper method of applying the molding, said that the best way seemed to be to apply a separate panel with a piping, which is made by the fabric being brought over a reed. The piping is ¼ in. in diameter and is fastened to the panel before it is inserted. The panel is pushed in and covers the opening. Mr. Bailey said that he had used half-oval drawn-steel molding with stubby-headed nails spot-welded on the flat side, instead of the lead-filled molding that Mr. Mercer considered too expensive. Being of steel, high baked enamel could be used and the steel could be dented without spoiling the enamel.

Mr. Kerr remarked that while fabric would eliminate the drumming noises that come from the roof, the roof was not the source of all noise; that he had stopped "booming" by placing his hand on the glass on each side, the "booming" being caused by the fact that the vibration of the glass and that of the chassis were in synchronism. Mr. Hill suggested that the rumble had been taken out of one series of Packard cars by adding 3 in. to the tail pipe of the muffler. Mr. Goddard added that lengthening the pipe or increasing its size steps the vibration up to a higher mile-per-hour speed and that, while it is still there, it is not so noticeable. The other vibrations due to the engine must be overcome by sound-proofing. Some of the noise is transmitted through the body-front structure and appears more in the front section of the roof. This frequently can be obviated by

padding the front portion between the first two ribs. Mr. Mercer replied that he had been told that morning by a body-builder that the trouble had been obviated by changing the method of bolting to the frame, by moving the first bolt, which had previously been put close up to the dash, back 9 or 10 in. Chairman Goddard thought that the steel dash, which is in almost universal use, being located at a point where the three-point support on the chassis has its effect, acted as a sounding-board and was responsible for about half the noise in the body that is not in the roof. He added that outside of increased quantity production the principal directions in which cost could be reduced lie in the use of some new material such as fabric by which the body could be covered faster than it could be painted; the study of the sequence of the various trimming and assembling units so that they shall not get in one another's way; and the study of demountable construction. Another speaker declared that, in his opinion, the only way to cut down the cost of bodies, outside of those custom-made, was by making them simpler, omitting all the frills and dispensing with as many moldings as possible. Chairman Goddard interpolated the suggestion that members should endeavor to avoid the use of the terms "pleasure car" and "sport model" and lay stress on the word "phaeton," which was approved at the meeting of the Standards Committee that was held in New York City in January of last year, to denote what has been known as "touring car."

Replying to Mr. Hill's query as to the reception of artificial leather by the public, Chairman Goddard said that the difference in price between a sedan trimmed in mohair velvet, and painted and varnished on the outside, and the black-enameled steel body-construction, trimmed in Spanish leather on the cushions and backs and imitation leather on the sides, made comparison difficult; that it was a question of utility; that the use of mohair velvet and of enamel gives the car a higher second-hand value. Mr. Day stated that he had the first California top made; that he had a car on which fabric had been used and had driven it over 60,000 miles, including a trip from California to Philadelphia and back, over very bad roads in Arizona and California; that it had been in the desert, in the snow, had been exposed to salt water and to the sun, in a climate where there is 8 or 9 months of heat, and that it looks very nearly as good today as when it was turned out. Mr. Williams inquired why the Society did not decide what to do to cheapen construction. He asked why mortised joints are necessary, instead of half-lapping them and sinking in a screw; why glue is used for certain parts rather than a screw; why a door is employed that laps three times and a weather strip is then put inside it; why not cut out the breaker-strip on the wood-frame door and lap the panel over the door; why specify silver plate-glass; why use five screws on a weather-strip when two or three would be sufficient; why use nails 1½ in. apart on a panel when the panel could be torn off if they were 4 in. apart. Mr. Steinbeck replied that such questions had been answered by Ford bodies, but Ford bodies could not be put on a Lincoln, Packard or Rolls Royce car; that different qualities are required from the body engineer as well as the chassis engineer. Chairman Goddard, in closing the discussion, said that the whole matter went back to quantity production; that operations can be conducted more simply and more cheaply by increasing the equipment but that the cost of the increased equipment of jigs, tools, fixtures, dies, forms and similar appliances required could be cared for only by spreading it over a sufficiently large quantity of completed bodies.

COOPERATION ANNUAL DINNER KEYNOTE

Between Fuel and Automotive Industries and Railroads and the Motor Truck

On Thursday evening, Jan. 11, 977 members and their guests attended the Annual Dinner of the Society in the ballroom of the Hotel Pennsylvania. Retiring President B. B. Bachman presided. With him at the speakers' table were prominent representatives of the various branches of the industry. Each table seated 10 persons but so large was the crowd that the use of both the main floor and the balcony was required and even then all available space was occupied. A musical program was rendered throughout the dinner by the popular Vincent Lopez orchestra of the hotel.

President Bachman questioned the advisability of holding future meetings of the Society during the week of the Automobile Show, because the number of counter-attractions at that time affected the attendance at the technical sessions, and cited the recent Production meeting in Detroit, which was notable on account of the large attendance and the value of the proceedings. After expressing his appreciation of the support that had been given him during his term of office by the members of the Society and bespeaking a continuation of it in behalf of his successor, President-Elect Alden, he introduced C. F. Kettering, who acted as toastmaster.

Mr. Kettering recalled the fact that at the dinner a year ago the subject of the address was, Has Business Really Turned the Corner?; that a number of predictions had been made for the coming year, most of which had come true; and that red paint and nickel-plating had again come into their own; that when Henry Ford was asked by Will Rogers at how low a price he could afford to sell his cars, Ford was quoted as saying that if he were to give away the car in a few months the sale of supply parts to replace those lost would pay for the car; that Ford was the only one to acknowledge what the rest leave to their customers to find out. Styles in motor cars, Mr. Ketting said, are exactly opposite to the styles in women's dress. It used to be the case that when a car would not start it was the fault of the starter; now it is the spark-plug, a set of which can be bought for $4. The fuel and the motor car industries have finally got together, the petroleum industry having recognized at last that the Society had in it some very good men; at a recent meeting a resolution was drawn up to the effect that the public will continue to use such fuel as the producers care to produce at such prices as they care to charge; that the engineers will build such engines as they please, which will give such mileage as they do notwithstanding the claims of the advertising manager.

The keynote of the address of Elisha Lee, Vice-President of the Pennsylvania Railroad Co., the principal speaker of the evening, was cooperation. On the principle of "live and let live," he pleaded for a unification of transportation effort and a division of the long-haul and the short-haul business, leaving the former to the railroads because they can handle it more efficiently, and the latter to the motor trucks, because they are peculiarly adapted to store-door collection and delivery. He believed that better results would be obtained by building roads through undeveloped sections and putting those sections in connection with the main arteries of transportation than by paralleling existing systems and dividing up the business that is barely sufficient to maintain the systems in operation at present. As an instance of over-development he cited two cities of the Middle West,

already connected by two railroads and by interurban electric lines, that were further joined by concrete roads over which several motor-truck lines are operating, thereby giving these cities greater transportation facilities than those enjoyed by New York City and Philadelphia, in the Country's most densely populated section. He said that if the volume of traffic were found insufficient to support both rail and motorbus lines it would seem only fair that the people should decide which form of service they desire and abandon the other; that in some localities the railroads were forced to run accommodation trains which did not pay half the cost of operation.

Mr. Lee did not believe that motor vehicles and concrete highways would erase the railroads from the map, as some persons have been led to believe, but that they would add greatly to the utility and efficiency of the railroads by rounding-out and completing the service, relieving the railroads of certain forms of burdensome and costly service that can be made attractively profitable to the motor vehicle, whose function is not to do what the railroads are equipped to do successfully but to do what the railroads are unable to do or to do only with difficulty. Although there are approximately 12,000,000 motor vehicles in the United States, the freight traffic of the railroads has nearly tripled since 1900. The question is one of wholesaling and retailing, the railroads handling best the mass transportation over considerable distances and the motor truck the freight pick-up work in the larger cities in less-than-carload lots. Coordination of this kind would be a vast improvement over the haphazard facilities usually at the disposal of shippers and consignees, who thus would have the benefit of a semi-express service. Whether terminal trucking should be done by the railroads or independently would require careful study, but the added complication of management and possible restrictive legislation seem to favor independent operation. The radius of the economic operation of motor trucks around a large city probably would be about 25 miles for less-than-carload lots; for longer distances greater efficiency might be obtained by the use of trucks for collection and delivery and the railroad for the intermediate line-haul. The use of motor-driven rail cars for passenger service on branch lines was, he said, a problem for the automotive engineer. The railroads were carefully studying every new design brought out but thus far none had been produced that could fully and satisfactorily fulfill the requirements. The primary purpose in both railroad and motor truck-transportation should be development along sane and sensible lines and the rendering of the maximum service of which each is capable.

Toastmaster Kettering, in introducing Herbert W. Alden, assured the members that the new president-elect, having carried the burdens of the industry for so long on his axles, could be counted on to carry those of the Society in an equally effective and satisfactory manner.

The new president outlined concisely some of the plans of the Society for the coming year. He expressed his gratification at the response of members who had been asked to serve on various committees, saying that out of 42 to whom requests had been sent only one had been unable to accept. Agreeing with Mr. Bachman, he believed that the technical sessions should be held at some time and place other than that of the annual automobile show; also that too much emphasis had been placed on the engineering side of the work and that efforts should be made to bring the engineering and production sections into closer relation. He announced that H. M. Crane had consented to continue for another year as Chairman of the Research Committee, and that B. B. Bachman would serve as Chairman of the Highways Committee. Special attention will be given to strengthening the local Sections of the Society.

USE OF LEATHER CLOTH ADVOCATED

Methods Employed Commercially for Testing Automobile Materials Outlined

J. B. Davis, in his paper on the Testing of Leather Substitutes and Top Materials, after a short historical introduction, discussed the various qualities of fabrics, and of leather cloth in particular, that should be embodied in specifications, and described the methods of determining these qualities by test. He showed that leather cloth was first manufactured in England in 1800 and in this Country in 1850. From a beginning in which a few hundred yards per day was considered a heavy production, the output has increased steadily, reaching in 1922 a total of 50,000,000 yd. Among its uses are one-man tops, curtains, upholstery, linings, gimps, welting, truck covers and lining, mudcaps, spring covers, and the curtains and covers of truck cabs. Other fabrics in use include muslin, drill, twill, sateen, moleskin and duck. The non-scratchable feature of the patent-leather finish gives to leather cloth many advantages over a painted and varnished steel surface and makes it particularly desirable in body construction. As the amount used on each car is small, quality is more important than price and the most desirable attributes are durability and appearance. With regard to appearance, the luster, smoothness, softness, finish and color must be considered. The desirability of other fabrics for specific purposes is judged by the weave, construction, thread-count, weight, and the like.

By lantern-slides the various pieces of laboratory apparatus were shown and the methods of conducting the several tests were described in detail. These tests covered the composition of the material; the uniformity of its weight; its resistance to wear as determined by rubbing; tensile and bonding strength; resistance to stretch and puncture; thickness; toughness and adhesion of the coating; resistance to water, shrinkage, fire, and heat; and the cleansability and resistance to gasoline. Other slides showed the effects of natural and artificial aging and of exposure, on water resistance, flexibility and toughness; the variations of skin properties, and the checking of the uniformity of pigments and fillers.

In the short time that remained for the discussion, which was participated in by G. W. Kerr, H. C. Mougey and C. M. Manly, Mr. Kerr brought out the point as to whether tests of uncoated fabrics from different makers did not show a difference in strength, even though the fabric might have the same characteristics of weave, weight and thread-count. This was answered in the affirmative, and was said to be due to the length of the fiber of the cotton, amount of twist and other factors. Replying to the query of Mr. Mougey, Mr. Davis stated that by combining the action of water and wind with that of a mercury-arc light, which reproduces the actinic rays of the sun, in a small cabinet, aging of material might be accomplished in a few days that formerly took from 6 months to 1 year. Mr. Manly added that in his experience during the war there was a great difference in strength between long and short-staple cotton; that twisting, mercerizing and different chemical treatments had great difference in their effect; that the simplest way to determine the effect of the number of twists is to subject the sample to test rather than to follow the course of the cotton through the mill.

Applicants *for* Membership

The applications for membership received between Dec. 15, 1922 and Jan. 15, 1923, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ALM, BRUNO, designer, Yellow Coach Mfg. Co., *Chicago.*

ALMEN, J. O., chief engineer, Almen Motors, Inc., *Seattle, Wash.*

ATKINSON, ROBERT, metallurgist and chemical engineer, Halcomb Steel Co., *Detroit.*

BEVERLEY, LIEUT. GEORGE H., Air Service, Kelly Field, *San Antonio, Tex.*

BROOKS, CAPT. JOSEPH L., Camp Holabird, *Baltimore.*

BROSSARD, EDWARD V., student, University of Minnesota, *Minneapolis.*

BROWN, NELSON TURNER, superintendent, Philadelphia Rapid Transit Co., *Philadelphia.*

COLEMAN, LAWSON DAVIDSON, student, Georgia School of Technology, *Atlanta.*

DAILEY, J. E., chief metallurgist, General Motors Corporation, *Detroit.*

DAVENPORT, GEORGE R., special engineer, Studebaker Corporation of America, *Detroit.*

DES ROCHES, PHILIP W., inspector transmission gearing department, Ford Motor Co., *Highland Park, Mich.*

DUNNING, LEIGHTON, engineer, John Warren Watson Co., *Philadelphia.*

DYKEMAN, G. WARREN, service representative, Detroit Cadillac Motor Car Corporation, *New York City.*

ECKERT, O. E., lubrication engineer, Transcontinental Oil Co., *Pittsburgh.*

EVANS, BOYD E., chief engineer, Detroit Motorbus Co., *Detroit.*

GADENHEAD, GEORGE LORIMER, student, University of Illinois, *Urbana, Ill.*

GRAMM, WILLARD J., chief engineer and factory manager, Gramm-Bernstein Motor Truck Co., *Lima, Ohio.*

HEAVRIN, W. C., lubrication engineer, Standard Oil Co. of Indiana, *Davenport, Iowa.*

HILBERT, FAYE W., motor-vehicle inspector, Sinclair Refining Co., *Buffalo.*

HILL, JAMES H., University Garage Repair Shop, *Evanston, Ill.*

HOLOWAY, PERCIE U., estimator and service salesman, Donovan Motor Car Co., *Boston.*

JOHN, WILLIAM EDGAR, vice-president, Hall Wheel Corporation, *Philadelphia.*

JORDAN, EDWARD S., president, Jordan Motor Car Corporation, *Cleveland.*

KEEGIN, CURTIS W., district manager, Cincinnati Ball Crank Co., *Cincinnati.*

KEISER, KARL W., student, University of Minnesota, *Minneapolis.*

KING, W. GRANT, president, King Sewing Machine Co., *Buffalo.*

LAUGHLIN, T. F., field service representative, Studebaker Corporation of America, *San Francisco.*

LUGUE, ADOLPH, gas engineer, 601 West 173rd St., *New York City.*

MAHER, GEORGE A., manager, C. M. Hall Lamp Co., *Kenosha, Wis.*

MARSH, W. R., superintendent, Locomobile Co. of America, *Chicago.*

MESINGER, FREDERICK, sales engineer, Norma Co. of America, *Long Island City, N. Y.*

MIDDLEKAUF, EDISON B., automotive purchasing agent, Texas Co., *New York City.*

OSMOND, CHARLES H., chemical engineer, Atlantic Refining Co., *Philadelphia.*

PECKHAM, HAROLD E., student, University of Minnesota, *Minneapolis.*

PIERCE, RALPH TRULL, assistant service manager, Donovan Motor Car Co., *Boston.*

PIERSON, D. M., assistant experimental engineer, Dodge Bros., *Detroit.*

RADO, K. P., chief engineer, Commodore Motors Corporation, *New York City.*

RAYMOND, ERNEST PETER, student, Tri-State College, *Angola, Ind.*

ROBERTSON, JAMES F., general manager, Defiance Motor Truck Co., *Defiance, Ohio.*

SCHIMELFENIG, MAJOR C. A., chief of the maintenance division, Ordnance Department, *City of Washington.*

SCHJOLIN, OLLE., designer, Yellow Coach Mfg. Co., *Chicago.*

SHEPARD, R. L., metallurgist, Shepard Art Metal Co., *Detroit.*

SHORT, BLADEN M., sales manager, C. G. Spring Co. of Michigan, *Detroit.*

SKINNER, ARTHUR A., sales manager, Leece-Neville Co., *Cleveland.*

SMARE, BENJAMIN M., engineer, General Motors Corporation, *Detroit.*

SULLIVAN, EDWARD C., sales engineer, Flint Varnish and Color Works, *Flint, Mich.*

TANNER, ALVIN G., chief draftsman, Locomobile Co. of America, *Bridgeport, Conn.*

VANDER, WILLIAM C., head of the department of automotive electricity, Technical High School, *Fall River, Mass.*

VANDERPOEL, ANDREW C., president, A. C. Vanderpoel Co., Inc., *New York City.*

VAUGHAN, HENRY POLK, student, Cornell University, *Ithaca, N. Y.*

WALKER, GEORGE L., assistant to president, R & V Motor Co., *East Moline, Ill.*

WILLIAMS, LEWIS E., dean of trade school, Youngstown Institution of Technology, Inc., *Youngstown, Ohio.*

ZAHOUR, R. L., student, Case School of Applied Science, *Cleveland.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Dec. 9, 1922 and Jan. 10, 1923. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

AIKEN, FRANK (M) ignition engineer, Atwater Kent Mfg. Co., *Philadelphia,* (mail) 401 Abbottsford Road.

ANDERSON, GEORGE POTTER (M) engineer, Graham Bros., *Evansville, Ind.*

BACON, DAY H. (J) designer, Ansted Engineering Co., *Connersville, Ind.,* (mail) 122 West 11th Street.

BAILEY, WALTER H. (A) automobile insurance, Royal Indemnity Co., New York City, (mail) 66 Hardenbrook Avenue, *Jamaica, N. Y.*

BAUM, SEYMOUR J. (M) works manager, Brewster & Co., *Long Island City, N. Y.*

BEAUMONT, JOHN SYDNEY (A) metallurgist, Ford Motor Co., of Canada, Ltd., Ford, Ont., Can., (mail) P. O. Box 501, *Walkerville, Ont., Can.*

BOWERS, GEORGE F. (E S) student, Purdue University, Lafayette, Ind., (mail) Box 35, 124 South Grant Street, *West Lafayette, Ind.*

BRADER, NORWOOD HAROLD (E S) student, Cornell University, *Ithaca, N. Y.,* (mail) 145 Cascadilla Park.

BRIDWELL, J. W. (M) chief engineer, Ruggles Motor Truck Co., *Saginaw, Mich.*

BROWNE, THEODORE C. (M) vice-president, Brush Laboratories Co., *Cleveland,* (mail) 3701 Euclid Avenue.

BULLARD, S. H. (M) vice-president, Bullard Machine Tool Co., *Bridgeport, Conn.*

BURCH, LOUIS D. (E S) student, Purdue University, Lafayette, Ind., (mail) 213 Vine Street, *West Lafayette, Ind.*

BURROWS, LEES J. (J) special service representative, Oakland Motor Car Co., *Pontiac, Mich.*

BUSSARD, ROBERT MCCLELLAND (E S) student, Purdue University, Lafayette, Ind., (mail) 150 Littleton Street, *West Lafayette, Ind.*

CARLSON, RAYMOND A. (J) draftsman, Rockford Drilling Machine Co., *Rockford, Ill.,* (mail) 1628 Fifth Avenue.

CARMIN, KENNETH ARNOLD (E S) student, Purdue University, Lafayette, Ind., (mail) 23 Waldron Street, *West Lafayette, Ind.*

CARSON, RAY EDGAR (J) draftsman, Robert H. Hassler, Inc., *Indianapolis,* (mail) 1226 North Illinois Street.

CAUTLEY, RANDOLPH (A) investigator of costs and special manufacturing problems, Wright Aeronautical Corporation, 238 Lewis Street, *Paterson, N. J.*

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Chronicle and Comment

"Phaeton" Coming Into Use

THE 1923 Handbook of Automobiles, recently issued by the National Automobile Chamber of Commerce, indicates that the recommendation of the Passenger-Car Body Division in reference to the use of the name "phaeton" instead of "touring car" is meeting with approval. This Handbook shows that 20 companies are now using that name for various types of open car.

Geography of Society Membership

THE following table shows approximately what proportion of the members of the Society reside in different regions of the United States and how many are located outside of this Country; the total number on the rolls of the Society being about 5300.

	Per Cent
Great Lakes States	47
Middle Atlantic States	31
New England States	8
Middle Western States	5
Pacific Coast States	4
Southeastern States	1
Foreign	4

Research Information Service

THE attention of the members is directed to the unique facilities offered by the Research Department Information Service. A complete index of the Society's publications, together with an exhaustive index covering domestic and foreign publications in the automotive and allied fields, is kept on file and is available for reference.

In addition to the published bibliographies indexed, the Department has unpublished bibliographies and lists of references that are invaluable for preliminary work along research lines. They include many of the important debatable subjects, such as lubrication; heat application to internal-combustion engine fuels; gears; magneto ignition; highway problem; chassis springs; steel, wire, and wood wheels and metallurgical matters. Copies of these bibliographies are held in the Department and may be had on request.

The Research Department has innumerable contacts with investigators and commercial and university laboratories, and is able to furnish data on researches projected, in progress or completed. Published reports of investigations, abstracts, indexes and handbooks are available either in the Department's own files or those of the Engineering Societies' Library.

Emergency Motor-Transport Plan

EVERYONE interested in transportation has been wondering what place the motor truck will take in the development of the transportation system of the Nation. Major Brainerd Taylor, of the Quartermaster Department of the United States Army, said at a recent meeting of the Washington Section of the Society that

> If this Country ever again has to face an emergency that threatens to paralyze its industries, its transportation and its everyday life, the United States Army plan for coordinating all available transportation would at least so mitigate conditions that the people of the Country would not suffer for want of food, fuel and other necessities. In the recent railroad-strike situation, the problem called for a solution by highway-transport engineers.

Major Taylor was detailed by the Army to prepare a plan to meet the threatened emergency. One of his fundamental points is that motor transportation can never, either in an emergency or daily commercial practice, replace the long-haul railroad service. It is expected that there will be a thorough discussion of matters bearing on the whole problem at the Automotive Transportation Meeting of the Society at Cleveland in April.

Standards for Roller Bearings

AMONG the many things that the Society of Automotive Engineers is endeavoring to standardize are the dimensions for inch-type tapered-roller bearings, on which a committee has been at work for some time. Ball bearings have been standardized so that the number of sizes available are limited to what is considered essential for the needs of the industries. Work is also progressing on standardizing metric-type roller bearings, a subject of equal importance. In the inch-type tapered-roller bearing field there are now over 200 sizes used in the automotive industry, and it is believed that about 50 sizes would probably care for practically all requirements.

This work is of great importance and, while it is evident as the work of standardization proceeds, that very many differences of opinion will be encountered, there is no doubt that standards can be established that will meet the requirements of all. It may appear at times that too rigid standardization might be unwise and result in a harmful restriction of initiative in the design and development of mechanical devices. Nevertheless, when standardization methods are not too drastic, they will always be found of value to the industry. Great savings in manufacture and in distribution will result, the methods of manufacture can be simplified, the range of sizes that will have to be kept in stock can be reduced, the capital investment of manufacturers and dealers will be less, and the ultimate consumer will be able to buy a standardized product at a price much lower than that of a product where the number of types of sizes made is far in excess of actual needs.—*Machinery.*

Taxing Gasoline Instead of Cars

THERE are important obvious advantages in a gasoline tax to take the place of the annual license-tax for highway purposes. The substitution of a duty on motor-fuel for the present system of vehicle taxation in England has been suggested by representatives of car-owners and dealers and seems to be meeting with much favor. The main feature of the scheme is placing a flat duty per gallon on all imported motor-fuel and abolishing or greatly reducing the present tax per car. It is alleged that a duty of 5d (10 cents) per gal. will produce £10,250,000 ($49,815,000 at normal exchange) revenues in 1924, sufficient to offset the present car-tax, the collections of which are used for highway purposes.

The main argument in favor of the plan is that it would distribute much more equitably than the present system the burden of taxation on motor-car owners. The existing tax, it is pointed out, is the same whether a car travels 400 or 40,000 miles per annum. An owner who has more than one car might pay the full tax on a car used but two or three times during the year. The fuel tax, on the other hand, takes into account automatically the horsepower, the speed and the weight of the vehicle, as well as the mileage. The proposed duty would bear directly on the car-owner in proportion to his use of the road and any evasion of payment would be impossible. Vehicles without internal-combustion engines would continue to be taxed as at present.

Automobile Shows

VARIOUS opinions have been given by men who are prominent in the industry as to the value of the National Automobile Shows that are held at New York City and Chicago each year. The following are some of the large number that are contained in a pamphlet which has recently been issued by the National Automobile Chamber of Commerce.

> The public has come to accept the completeness, size and grandeur of the National shows as a direct expression of one of America's largest and most virile industries.
>
> The shows teach the makers that to see themselves as others see them is not always flattering, but sometimes economical, and always wise.
>
> A show is a business barometer, as well as a guide to the general trend in design and construction.
>
> The material man, the parts-maker, the manufacturer, the dealer, the salesman and the consumer meet at the shows for an exchange of thought.
>
> The shows are forums at which all that the industry has done is brought before the public in the only language that never fails and none can misunderstand, the language of actual performance.
>
> More can be learned in one hour at a show than in a week of visiting the establishments of the makers or by reading any quantity of books or advertising literature.
>
> The shows are the cheapest form of advertising and are therefore effective in reducing the cost of cars.
>
> The shows, with the elaborate publicity campaigns that accompany them, reach a large public group that is not exactly motorwise but keenly interested and forms the nucleus of active "prospects."
>
> A show is advertising backed by personal contact.
>
> We can check our advertising returns from the show, whereas there is no satisfactory check on any other form of advertising.
>
> The newspapers give the shows an amount of space that could by no possibility be purchased or obtained in any other way.
>
> A show is cooperative advertising by the whole industry.
>
> The value of the National Automobile Show is proved by the fact that it is the oldest industrial show that has been in continuous existence in this Country, if not in the world.
>
> The shows are to the manufacturer and the dealer what advance-agents are to the theatrical business.

A New Type of Engineer

CLOSE students of transportation tell us that the motor vehicle is entering an era of unprecedented development as an arm of the national transportation system. It is significant that several great railroad systems have organized departments to study intensively the coordination of motor and rail transport. Of even greater significance is the fact that one or two railroads have actually purchased truck fleets for use at their terminals. Recent joint meetings of Government, transportation and automotive representatives reflected the increased interest in the motor truck, motorbus and motor rail-car as transportation media.

This brings us to the point where a new type of engineer is needed, the motor-transport expert, versed not only in the construction of motor vehicles, but possessing a full knowledge of how they should be operated and maintained to secure from them the maximum of efficiency. Few motor-haulage operations have been lucrative investments; the difference between those companies achieving a substantial profit and the others can generally be traced to the presence or absence of a competent motor-transport engineer. The motor-transport engineer must possess the knowledge of traffic control characteristics of the successful railroad engineer; he must be a judge of good equipment in the form of vehicles, bodies, loading mechanism and repair tools; he must possess the accountant's respect for costs and be able to supervise their accurate compilation. Truly, here is an opportunity for the analytical mind of the engineer.

Predictions are dangerous, but one may be hazarded here. Automotive engineers must turn their attention toward the operating end of the business; the largest percentage of the Nation's motor-transport engineers will be graduates of the automotive industry, particularly from its engineering branch. It seems logical for the Society to become active along automotive transportation lines, especially in exerting its influence to promote an intensive cooperative study of motor-vehicle operation and its problems. The Cleveland Automotive Transportation meeting is the first step in this direction; it will bring together the engineers who design motor trucks, buses and rail-cars, and the motor-transport engineers whose job it is to make them serve at a profit.

Tendencies in High-Speed Marine-Engine Design

By J. G. VINCENT[1]

MOTORBOAT MEETING PAPER *Illustrated with* DRAWINGS

IN this paper there are discussed the general requirements of a comparatively new type of marine engine, that is, the high-speed type. The need for light weight is discussed and it is pointed out that aircraft-engine design has established a good precedent to follow, particularly with reference to crankshaft, connecting-rod, piston, cylinder and valve design.

Detailed discussion then follows concerning the requirements of this type of engine in respect to cooling, lubrication, starting, idling and general operation. The equipment to be furnished with the engine is covered in a general way and the installation requirements are touched upon.

GASOLINE marine-engine design is apparently entering a new phase of development. It seems that the advances in aircraft-engine construction are primarily responsible for this evolution. Not so many years ago there was a somewhat similar well-defined stage in the progress of marine-engine development, when certain automobile-engine principles were applied with advantage to motorboat engines. The more important of these features were electric-starting and lighting equipment, enclosed valve-mechanism and general improvements tending toward weight reduction and more silent operation. It should not be inferred that marine-engine designers have stood still while other automotive engineers have advanced; this is decidedly not the case. There are many points in connection with marine-powerplant design that are distinctly foreign to other automotive fields and in this paper particular stress will be laid on these problems that have been successfully solved by marine designers.

At present it appears proper to classify gasoline marine-engines under three types; (a) the heavy-duty, slow-speed, (b) the medium-speed, medium-weight and (c) the high-speed, light-weight variety. Although this paper is really intended to cover only the last type it may not be out of place to discuss briefly the requirements that lead to these three essentially different types of engine. Basically, the speed desired of the boat under consideration determines which of the three types of engine is the most suitable and although there is a certain permissible overlapping in the adoption of each type of engine for each service, nevertheless the boundary lines between the slow-speed, the medium-speed and the high-speed engine are pretty clearly defined.

Below 15 m.p.h. the most efficient powerplant for marine service is undoubtedly what is termed the heavy-duty type with an engine speed not exceeding 800 r.p.m. at the very maximum, with 600 r.p.m as a standard to be preferred. Between 15 and 30 m.p.h. the requirements call for a medium-speed engine, turning from about 800 up to about 1200 r.p.m. Above 30 m.p.h. a high-speed engine is demanded, which if direct-connected may be called upon to run as high as 2600 r.p.m. for speeds between 50 and 60 m.p.h.

The demands on a powerplant for high-speed marine service do not differ greatly from the requirements of aircraft usage. In both cases reliability is paramount, light weight very important and economy and smoothness highly desirable. The load characteristics are almost identical, air and water propellers both requiring horsepower varying approximately as the cube of the speed. From this it can be inferred that aircraft engine-design, on which an enormous amount of work has been expended during the last few years, can be used as a basis for the design of this comparatively new type of gasoline marine engine, and this applies particularly to such important elements in the design as the crankshaft, bearing proportions, cylinder construction, valve proportions and cooling arrangements and gas velocities through the passages. This all does not mean, however, that a successful airplane engine can be installed in a boat without any changes in design, and give equally efficient service as in the air. The high-speed marine-engine requires special study in many respects. The more important considerations are outlined under the following headings:

(1) Cooling
(2) Lubrication
(3) Starting
(4) Idling and General Operation
(5) Clutch and Reverse-Gear
(6) Engine Accessories
(7) Accessibility
(8) Direction of Rotation
(9) Installation Requirements

COOLING

Paradoxical as it may seem, the efficient cooling of a marine-engine offers more problems than are met with in other automotive applications of water-cooled internal-combustion engines. While there is an inexhaustible supply of cooling water available, its temperature is considerably below the most efficient operating temperature of the engine and the fact that part of the engine is generally located considerably above the water-level presents another phase of the cooling problem.

The general requirements are best met by a system such as is shown in Fig. 1. The water is taken in from the sea through a scoop suitably located so as to be submerged at all speeds. A shut-off valve is arranged close to the inlet for use when working on piping or connections below the water-line. A check-valve may be installed next in the line to prevent the water discharging back into the sea when the engine is stopped. A gear water-pump is driven from a suitable accessory shaft and, in the installation shown, delivers water to the exhaust-manifold jacket first. The object of this procedure is to raise the temperature of the water more nearly

[1] M. S. A. E.—Vice-President in charge of engineering, Packard Motor Car Co., Detroit.

to that which will correspond to maximum engine efficiency, a cylinder-jacket outlet water-temperature of 140 to 160 deg. fahr. being desirable. It should be noted that the pump delivers water to the highest point of the exhaust-manifold jacket so that with the engine at rest this part of the system will remain full of water, even should the check-valve mentioned previously be omitted or fail to function. After traversing the length of the exhaust-manifold the water is led from the bottom of the manifold jacket to the bottom of the cylinder jackets through a suitable distributing manifold. The outlets from the cylinder jackets communicate with the inlet-manifold water-jackets, thus giving the benefit of the hottest water available for vaporizing the fuel. After leaving the inlet-manifold jacket the water is either discharged overboard or by-passed back to the pump intake. In certain marine engines, designed by me, a thermostat control has been developed which automatically maintains the correct operating-temperature. As shown on the diagram, a thermostat valve of conventional sylphon construction is mounted in a casing on the intake-manifold jacket and whenever the water temperature rises sufficiently high the bellows expand and open a valve that permits the water to flow overboard. At lower temperatures the water is by-passed back to the pump inlet and, through being recirculated in this manner, becomes warmed-up very quickly, assuring good idling and acceleration. A very important feature of this system is the "pressure"-valve shown in Fig. 1. This is a spring-loaded valve opening toward the pump inlet which prevents the system becoming airbound when starting-up, in case the jackets and piping should not be completely filled with water. It will be understood, of course, that this valve will open only with hydraulic pressure on its under surface so that, if there is any air in the system this air will be first expelled through the bleed shown at *a* in Fig. 1, which passage is normally used to discharge water into the exhaust-pipe for cooling purposes.

With a cooling system as described no manual adjustment or other attention on the part of the pilot or mechanic is required. It is advisable, however, to install a distant-type thermometer in the inlet-manifold jacket as a check on the correct functioning of the system. An addition to the cooling system that in some installations proves desirable consists of the routing of the main sea-water supply through an oil-cooler on its way to the engine pump; such a construction is shown dotted in Fig. 1. This matter will be discussed at greater length under the next heading.

Lubrication

In a high-speed marine engine, as in an aircraft engine, the provision of adequate lubrication to all moving parts is a matter of first importance. Furthermore, in contrast with slower-moving machinery, the lubricating system has the additional duty to perform of carrying away the heat from heavily loaded, high-speed bearings, as well as of serving to cool the interior of the pistons to a moderate extent. Needless to say, good engineering practice dictates full pressure lubrication carried to all crankshaft bearings, with positive lubrication to all camshaft and accessory-drive plain bearings and reliable splash-oiling to all gears, anti-friction bearings and piston-pin bushings. The reverse-gear, when built into an integral extension of the crankcase must also be considered as a part of the engine and continuous lubrication should be provided for all of its bearings, bushings, and gears.

In other respects, however, the lubrication problem is very different on the water from what it is in the air. For instance, means for cooling the oil in aircraft-engine service do not present much difficulty due to the tremendous blast of air available. In fact, in many installations the surfaces of the oil-tank and crankcase are considered ample for the purpose, whereas in other cases a comparatively small oil-radiator is exposed to the slip-stream. In marine service no such favorable conditions exist, since there is only a moderate amount of ventilation in the engine compartment and the crankcase itself is thoroughly shielded from what little draft might be available. This practically compels the adoption of a dry sump-system, and adequate provision must be made for cooling the oil in the external oil-tank; this is done best by circulating sea water through suitable cooling-coils immersed in the oil. A typical construction is shown in Fig. 2. In this case all the water used to cool the engine is allowed to flow through the cooling tubes. In other installations a separate scoop is arranged to circulate sea water through the oil-cooler but this does not appear to be as good practice as the system previously described since it entails more piping and joints which are likely to develop leaks. Before passing the subject of oil-cooling, it might be well to state that owing to the relatively low thermal conductivity of oil it is necessary to spread the oil over comparatively large surfaces to get the best results.

Assuming that the lubrication of the engine has been satisfactorily carried out and that adequate oil-cooling means have been provided, there still remains the problem of preventing a surplus of oil reaching the combustion-chamber while the engine is idling or running under light load. This can be accomplished to a certain extent by proper piston and ring design but it also appears desirable in many cases to lower the oil pressure under these conditions. This can be accomplished by either a fixed or an adjustable "bleed" arranged so that at low speeds the capacity of the oil-pump is insufficient to build-up the working pressure, and this simple method has proved very satisfactory in many instances.

The method of "scavenging" the oil from the crankcase and reverse-gear compartment, providing the latter communicates with the former, is somewhat simpler in the high-speed marine engine than in the case of the aircraft engine, since the inclination of the marine engine while operating at high speed seldom exceeds 15 deg. with the bow naturally uppermost, while in the air it is necessary to figure on the steepest climb or the steepest glide possible which at times may reach an angle of 45 deg. or more. This means that for marine service a single scavenging-pump with the inlet located at the rear end of the crankcase will serve to keep the oil-level down so that the connecting-rods will not dip or the oil tend to leak out of the rear bearing.

Starting

The starting of a marine engine of large power presents a problem of more than ordinary difficulty when the various limitations are considered. First, since the high-speed engines under consideration are being developed to obtain the maximum performance for the minimum weight, it follows that the weight of the starting equipment must be kept as low as possible. This implies the necessity for high efficiency on the part of the starting mechanism. The electric starter has proved to possess the necessary qualifications for the task. In the past there has been a tendency to adopt a rather small starting motor geared to run at a very high speed,

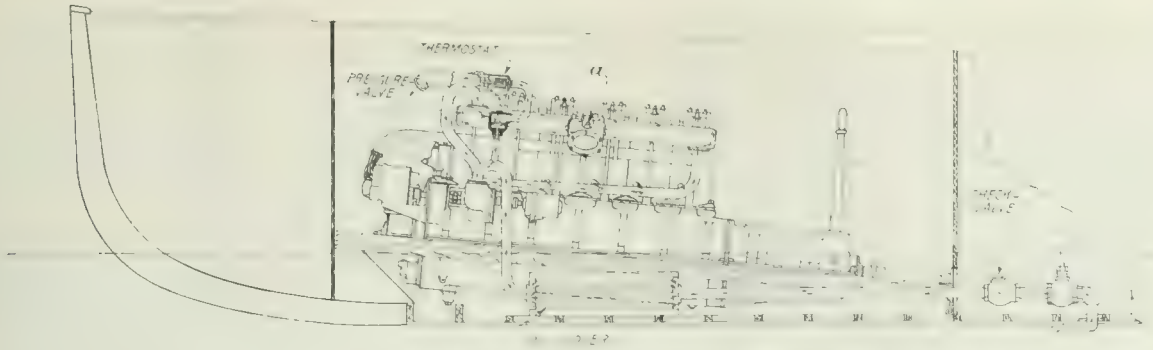

FIG. 1 – COOLING SYSTEM FOR A MOTORBOAT ENGINE

which naturally entails a train of gears having more or less irreversible characteristics. The result is that to protect this mechanism from damage in case the engine backfires it is necessary to add some more or less complicated anti-kick device. Therefore, the mechanism becomes unduly complicated and includes some very heavily stressed parts that are subject to failure.

The difficulty encountered with the extremely low-geared electric starters leads to the conclusion that undoubtedly more satisfactory operation can be secured with a starting motor having a considerably higher gear-ratio, such as is normally employed in automobile practice. In other words, instead of a small starting motor geared perhaps 100 to 1, it seems preferable to employ a much larger starting motor geared about 15 or 20 to 1. This, of course, entails the development of larger and more powerful starting motors and somewhat heavier apparatus, but it appears that the demands for the utmost in reliability must offset other considerations.

The failure of the starter to operate should the engine stall while maneuvering in close quarters may lead to a disastrous collision and, similarly, should the starter fail after the engine has been shut-down for any reason in a heavy sea, this may lead to serious consequences. Special stress is laid on these points because undoubtedly starter trouble has been the predominating difficulty experienced with high-speed marine engines.

IDLING AND GENERAL OPERATION

Next in importance to prompt starting of these engines comes the requirement for good idling to assure the boat being under control at all times. This is largely a matter of proper carburetion, although efficient methods of controlling the cylinder lubrication and the jacket-water temperature are contributing factors in obtaining the proper result. The general requirements are very similar to those obtaining with aircraft engines, good acceleration and smooth running at all throttle positions being essential. Although gasoline economy is perhaps not so important considering the weight of fuel that is to be carried, the economic considerations cannot be overlooked. With a high-efficiency engine of the type under consideration it is possible to secure a gasoline consumption as low as 0.53 lb. per b.hp-hr. without resorting to unduly high compression-ratios.

To secure good idling and low-speed operation it is necessary to provide for ample flywheel effect. Unfortunately, in the average boat installation it is not possible to locate a large-diameter flywheel at the rear end of the crankshaft since, due to the inclination of the engine mounting, it is necessary to keep the depth of the engine at this point as small as possible. It is therefore common practice to place the flywheel at the forward end of the crankshaft where usually a fair diameter can be secured. It is desirable from many standpoints to enclose this flywheel; this is not only a matter of securing protection from the revolving flywheel which is usually provided with gear teeth for starting-motor engagement but it is also highly important to prevent the possibility of water that may collect in the bilge from being thrown over the engine by an exposed flywheel It has frequently happened that in a heavy sea sufficient water was shipped to immerse the flywheel partially, putting the engine out of action through water being thrown into the carbureter and over the ignition system.

It is practically essential to provide a tachometer on an engine of this character. This instrument will fur-

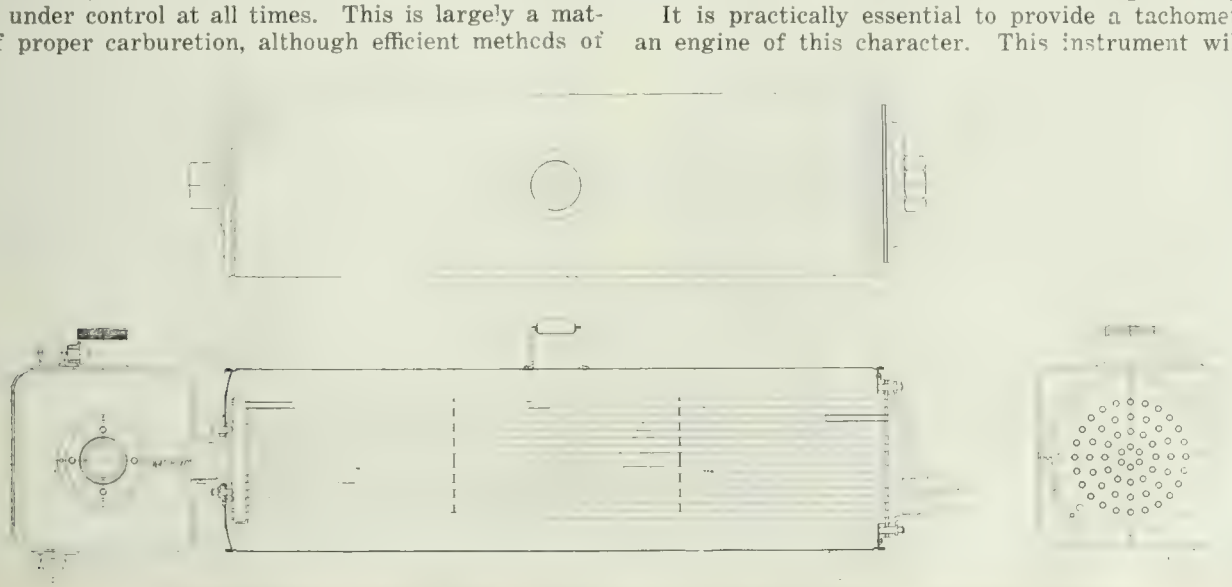

FIG. 2—DIAGRAM OF A TYPICAL SYSTEM FOR COOLING THE OIL USED TO LUBRICATE A MOTORBOAT ENGINE

nish a positive index to the operating conditions of the engine at high speed. A somewhat debatable question is the provision for a governor. In the hands of a thoroughly experienced man, a governor is probably a more or less useless accessory but where twin engines are employed and long cruises are undertaken there is no doubt that the installation of an engine governor is warranted. This is to protect the engine from not merely racing occasionally in rough water but from damaging itself should the clutch slip out of engagement, the propeller-shaft break or the load be removed from any similar cause.

Clutch and Reverse-Gear

The multitude of design problems involved in a suitable marine clutch and reverse-gear have been thoroughly studied in the many years during which the marine-engine has been developed and, aside from possible improvements in materials, there is probably not much room for development. The forward clutch is almost invariably of the toggle-operated multiple-disc type and, excluding perhaps the need for rather frequent adjustment, this can be considered a perfectly satisfactory mechanism. It is also essential to design the clutch so as to minimize the drag in the neutral position so far as possible. The reverse-gear is generally of the planetary type with an external contracting band. Considerable detail study is necessary to make this design thoroughly satisfactory and in the majority of installations the clamping means for the planetary drum are woefully inadequate. This is obviously merely a matter of suitable proportioning of parts made from proper materials and sufficient pressure on the band to provide the necessary braking effect. The lubrication of the clutch and the reverse-gear on the high-speed engine is a matter deserving serious consideration. Although the mechanism revolves as a unit when going ahead there is need for adequate lubrication when in neutral or reverse. If the reverse-gear housing forms a unit with the crankcase, it is good practice to extend the circulation of the engine lubricating system to the reverse-gear. This can be readily accomplished by suitable passages drilled in the crankshaft and in the interior of the reverse-gear. The surplus oil, of course, must be returned to the oil-tank by a suitable suction-tube located in the bottom of the reverse-gear housing and in the majority of installations it is permissible to allow all the return oil from the engine to flow back through this suction-tube so that a single scavenging-pump will be all that is required.

There is some question as to the best method of obtaining a floating connection that should be provided between the engine crankshaft and the reverse-gear drive-shaft; in some cases the crankshaft is positively located while the reverse-gear is allowed to float and assume some fixed position in relation to the propeller-shaft. In any case suitable precautions must be taken to prevent the propeller thrust being absorbed by the crankshaft unless this is contemplated in the design and proper means provided.

The deep-groove radial-type of ball bearing has proved to be very satisfactory for absorbing the thrust of the propeller-shaft, and is undoubtedly preferable to the ordinary ball thrust-type since the radial bearing is capable of carrying a certain radial load in addition to the thrust load from either direction, this resulting in a more compact design. As this bearing sustains a heavy load, careful provision must be made for lubrication and cooling. This can perhaps best be done by casting a downwardly extending trough on the side wall of the reverse-gear housing, this trough carrying the oil that is thrown out from the revolving reverse-gear to the bearing through suitable passages. Means should be provided to prevent the oil-level in the bearing housing from rising too high and suitable packing should be installed to prevent surplus oil from leaking out at the rear end.

Engine Accessories

The accessories to be provided for on high-speed marine engines do not differ materially from those for other types of engines. In regard to the ignition system, it appears that the battery type has certain advantages over the magneto ignition commonly employed in aircraft engines today. This is primarily because a storage-battery must be carried in any event for the starting of the marine engine, whereas this is not the case in airplanes, electric starting having made little headway on aircraft engines. It follows that a generator also is required on a marine engine. It appears that 12 volts represents a good standard for this service. This voltage is suitable also for the running lights of a medium-sized boat but in larger boats, where heavy lighting requirements are met, it is customary and desirable to install an independent lighting outfit that usually develops 32 volts. In these cases it is probably better to divorce the main electrical system from the engine system since the batteries used for lighting would not ordinarily be suitable for the heavy discharge of current required for starting purposes.

Gasoline is usually fed to the carbureter by an air-pressure system and it is therefore necessary that the engine equipment include a small air-pump to develop the 2 or 3-lb. pressure required. While on the subject of the gasoline-feed system it may be well to state that it has become standard practice recently in aircraft engines to abandon the air-pressure system in favor of the gasoline pump preferably of the gear type. However, in a boat the possibility of gasoline leaking into the bilge always presents a very serious menace. In all gasoline pumps, except those of the sylphon type, packing is required around the shaft, which packing requires frequent inspection and adjustment. While touching on the gasoline system it might be well to enter a plea for very generous filter-screens in the gasoline line. Experience has shown that due to condensation and other causes water is very apt to accumulate in the gasoline system of a boat and there is a tendency for a certain amount of rust formation which is very apt to cause stoppage of the carbureter jets. For a similar reason it is advisable to use brass piping for all gasoline lines, and the use of aluminum in carbureters should be discouraged as it has been shown that aluminum carbureters tend to corrode in marine service, this not occurring with brass carbureters.

It has become customary to install remote control-switches for the electric starter since this obviates the necessity of running heavy cables up to the manual starting-switch located near the pilot. With the remote control-system a small push-button serves to operate the remote control-switch by a solenoid and the connecting wires can be small.

Accessibility

Since the high-speed type of marine engine under consideration is used exclusively in fast boats, it follows that engine-room space is, as a rule, very limited as the engine is naturally large in comparison with the overall length of the boat. Furthermore, a boat of this type has,

as a rule, a comparatively narrow beam, so that in many installations the engine pretty completely fills up the compartment provided for it. It is therefore necessary, when designing an engine of this type, to give very careful consideration to the location of the various accessories and other parts of the engine requiring adjustment or inspection. Generally speaking, the Vee-type engine lends itself particularly well to these requirements as it is naturally compact, light in proportion to its power, and, with overhead valves and the carbureters located in the Vee, these more important parts are readily accessible from above.

In discussing accessibility it is natural that the question should be raised as to the merits of hand-holes provided in the crankcase for access to the connecting-rod and main bearings. Heretofore, particularly in the larger and much heavier slow-speed engines, it has been customary to make such provision but the reasons behind this practice do not apply to the class of engine under discussion. For instance, the former type of engine will weigh 15 lb. per hp. and upward, the latter type probably not one-fifth as much. This means that it is a comparatively simple matter to remove the high-speed engine from the boat whenever necessary for major overhauling, and this is a far more satisfactory procedure than attempting to work in the cramped quarters of the engine-room. Furthermore, due to the high-grade material employed, the light reciprocating parts and the excellent lubrication of the high-speed engine, its bearing life is exceptionally long. Again, the engine being designed as compactly as possible, there is little opportunity for providing adequate inspection-openings without sacrificing strength in the crankcase. When it is necessary to give the engine what is termed a "top overhaul," that is, grind the valves, etc., it is usually essential to remove the cylinders, and this of course leaves the crankcase cylinder bores available as inspection openings.

Direction of Rotation

With the powerful high-speed engines used in the many light fast boats at the present time the element of torque reaction has a considerable influence on the steering of the boat and for craft engaged in racing where turns around the course are invariably to the left it is of considerable advantage to have the torque reaction assist in banking the boat on the turns. This means that with a single-screw installation the engine should turn clockwise viewed from the rear, this requiring a right-hand "wheel." Such an engine is also used on the right-hand side of a twin-screw installation, the left-hand engine revolving in the opposite direction. It therefore follows that the right-hand engine, if of the vertical type, should have the exhaust-manifold on the right-hand side and the water outlet on the same side. Similarly the carbureter should be on the left-hand side, together with whatever accessories can be conveniently arranged on that side.

Installation Requirements

It is essential in the design of a high-speed marine engine for the engine designer to work in close harmony with the hull designer to secure the best possible combination of the engine and the hull. The proper distribution of weight in a high-speed boat determines its performance to a large extent and, while individual requirements will vary considerably, there are certain fixed principles that may be laid down. Among the most important is the depth of the crankcase below the center-line of the crankshaft and especially at the rear end it is necessary to keep this dimension down to a minimum; furthermore, a low center of gravity is very desirable. Suitable provision must be made for continuous stringers to support the engine and to avoid weakness, no jogs or recesses should be required in these timbers. Care must be used in locating the oil, water and gasoline connections so that they will be readily accessible in the boat. Standard pipe-threads should be used wherever oil, water and gasoline connections are made to the piping installed in the boat, since this gives the boat-builder the widest latitude in selecting standard fittings for making the required connections.

The engine should be furnished with spark, throttle and mixture controls in such positions as to connect readily with the controls used in the boat. The exhaust-manifold, which is naturally included with the engine equipment, must be designed so that the exhaust-pipe can be connected readily without necessitating any sharp bends adjacent to the manifold. The carbureter should be constructed so that all gasoline leaks due to a flooding carbureter will flow to a common sump that can be connected to a drain-pipe to go overboard. The carbureter air-intake should be carried to a point where a back-fire is not likely to set fire to any possible accumulation of gasoline or oil in its neighborhood.

The reverse-gear operating lever should preferably be capable of attachment on either side of the engine to suit different installations. The propeller-shaft coupling should be furnished with the engine and conform to accepted marine standards.

Finally, complete installation drawings should be furnished to the boat-builder, together with a power curve of the engine, recommendations as to maximum speed, diagrammatic layouts of the piping and wiring systems, and requirements in regard to oil and gasoline-tank capacities.

As typical of high-speed marine engines there are appended below complete specifications of both a 6-cylinder and a 12-cylinder engine, the former to develop from 150 to 200 hp., and the latter from 300 to 400 hp., the low rating in each case applying to low-compression engines adapted to run on commercial gasoline, and the higher rating to the same engine equipped with high compression and running on doped fuel for racing purposes.

Bore, in.	5
Stroke, in.	5¼
Displacement, cu. in.	
6 Cylinders	618
12 Cylinders	1,237
Cylinder Arrangement	
6-Cylinder Engine	Vertical in line
12-Cylinder Engine—Two rows of six cylinders, included angle 60 deg.	
Cylinder Construction	Built-up individual steel type
Valve Mechanism	
Single enclosed overhead camshaft over each block of six cylinders	
Valve Actuation	Rocker-arms
Cylinder Center Distance, in.	
6; except between No. 3 and No. 4, 7¼	
Connecting-rods	
9 in. centers, straddle type for 1237-cu. in. engine, I-beam section	
Connecting-rod Bolts	
12-Cylinder Engine, Plain Rod, two 7/16-in. bolts	
Forked rod, four 5/16-in. bolts	
6-Cylinder Engine, Plain Rod, four 5/16-in. bolts	
Piston Material	Die-Cast Aluminum
Piston-Rings	
Four, concentric type, lower ring below piston-pin, and ground taper	

Piston-pin Diameter, in.	1¼
Piston-pin Bore, in.	⅞
Valves	
Number per Cylinder	2
Diameter in the Clear, in.	2
Lift of Inlet-Valve, in.	7/16
Lift of Exhaust-Valve, in.	⅜
Angle of Seat, deg.	30
Valve-Springs	
Type	Helical
Number per Valve	2
Valve-Timing	
Inlet	Opens 10 deg. late, closes 45 deg. late
Exhaust	Opens 48 deg. early, closes 8 deg. late
Crankshaft	
Main Journal Diameter, in.	2⅜
Crankpin Diameter, in.	2⅛
Effective Length of Connecting-Rod Bearing, in.	2 3/16
Effective Length of Intermediate Main Bearings, in.	1 7/16
Effective Length of Center Main Bearing, in.	2 11/16
Crankcase Material	
Type	Aluminum Box Section, split on centerline of shaft. The lower half has continuous flanges for bolting to engine timbers and includes reverse-gear housing. The lower halves of the main bearing are carried in the lower half of the crankcase
Ignition	Battery-generator type, consisting of complete two-spark distributor for each set of six cylinders
Water-Pump	Gear type, independent pump for each set of six cylinders
Carbureter	Two duplex 2-in. plain-tube carbureters for 12-cylinder engine; two 2-in. single carbureters for 6-cylinder engine
Oil-Pump	Duplex-gear type, one scavenging-pump, one pressure-pump
Electric Starter	Automatic gearshift with 15 to 1 reduction
Starting Switch	Remote-control type
Generator	Third-Brush regulation, 12 volts
Exhaust-Manifold	Water-Jacketed, built-up sheet-steel type
Water-Temperature Control	Full-Automatic thermostat system
Forward Clutch	Multiple-Disc type, pressure-lubricated, toggle engagement
Reverse-Gear	Planetary type, woven-asbestos lining on brake-band
Thrust Bearing	Deep-groove, radial ball-bearing type
Weight, lb.	
6-Cylinder Engine	900
12-Cylinder Engine	1,150
Rating of Six-Cylinder Engine, hp.	
5 to 1 Compression-Ratio at 1800 R.P.M.	150
6½ to 1 Compression-Ratio at 2000 R.P.M.	200
Horsepower of 12-cylinder engine is double that of the 6-cylinder engine in each case	

It has been attempted in this paper to point out that the tremendous increase in speed of displacement boats has created a need for a new type of marine engine. It is believed that the requirements of the service have been pointed out sufficiently well to make a convincing argument in favor of the special light construction described as compared with the heavy construction used heretofore in slower-speed marine engines. There are undoubtedly a number of valuable lessons to be drawn from aircraft-engine design and in many respects the materials used and the method of design will be identical in both cases. In other respects the requirements of marine service differ from other automotive practice and there is plenty of room for the marine designer to show his ingenuity.

FEBRUARY COUNCIL MEETING

THE meeting of the Council held in New York on Feb. 26 was attended by President Alden, First Vice-President Crane, Vice-Presidents Warner and Masury, Past-President Bachman and Councilor Scott.

The financial statement as of Jan. 31, 1923, showed a net balance of assets over liabilities of $120,404.54, this being $10,229.22 less than the corresponding figure on the same day of 1922. The income of the Society for the first 4 months of the current fiscal year amounted to $91,950.59. The operating expense during the first 4 months of the current fiscal year was $93,532.15.

Fifty-seven applications for individual membership and ten for student enrollment were approved. The following transfers in grade of membership were made: From Associate to Member, E. W. Kimball, G. L. Crosby, C. S. Price; Foreign Member to Member, Charles A. Bennet, E. N. Rahusen, Wallace M. Van Deusen; Service Member to Member, Gordon R. Pennington; Member to Service Member, J. H. Geisse; Junior to Member, Erwin L. Bare, Louis C. Huck, John F. Wyzalek, W. E. Shively; Junior to Associate, M. Lair Hull.

It was reported that up to Feb. 26, 1923, 165 applications for membership had been received during 1923, as compared with 113 received during the first 2 months of 1922, and 136 during the first 2 months of 1921.

The following appointments to the Standards Committee were made:

C. A. Carlson	Motorboat Division
F. W. Davis	Truck Division
L. R. Buckendale	Axle and Wheels Division
H. L. Williams	Iron and Steel Division
E. W. Ehn	Iron and Steel Division

It was decided not to assign the subject of tire-chain clearances for consideration in connection with the standardization activities of the Society.

Walter F. Graham was appointed to serve as the Society's representative on the American Society for Testing Materials Committee on Malleable Irons.

R. E. Brown was appointed by President Alden to serve as the Society's representative on the Consulting Committee on Lumber Standardization, City of Washington.

T. J. Litle, Jr., was designated a member of the Research Committee.

A. L. Riker was appointed a member of the Highways Committee.

The next meeting of the Council was tentatively scheduled to be held in Cleveland on April 25, the day preceding the opening of the Society's Automotive Transportation Meeting which will continue until April 28.

Immediate Possibilities of Commercial Airplane Service

By C. G. Peterson[1] Annual Meeting Paper

STATING that the heretofore impassable barriers to commercial aviation have been costs and the lack of desire of the public to fly often, or to fly at all, the author proposes that the public, which must constitute the market for airplanes on a commercial basis, be educated by a demonstration of safe and reliable pay-load airplane-service extended over an indefinite period, and outlines a plan that includes the surmounting of cost deterrents.

He marshals arguments and statistics to show that such a public demonstration can be made by a proper and adequate equipment, operation and maintenance of the Aerial Mail Service, since it has been demonstrated already by this service that mail can be carried safely by air and that it can be flown through hard Northern winter weather. His statistics include a consideration of the present volume of mail, special-delivery-letter and parcel or package-carrying possibilities as revenue producers, being inclusive also of the postal rates necessary under such conditions.

An estimate on the cost of equipping and operating a night-flying line between New York City and Chicago, based on present equipment, is given. The author believes that passenger traffic would follow unsolicited just as soon as the public realized that the mail airplanes were flying safely and on-time.

THIS meeting is to be devoted to a discussion of the design of commercial airplanes. What are they, and what will they be used for? Let us consider first a few unpleasant facts; then I will point out how commercial airplanes can be used and what they will be used for. We are entering the fifth year after the war, in what had been predicted to be the age of commercial aviation. But during these years not one American company that I know of has sold a single commercial airplane in the United States at a price to meet the construction cost of the airplane, the engine, and its accessories. To be sure, some new airplanes have been built and have been sold, but they have been equipped with wartime engines. Some new engines have been sold, but they have not often been placed in new airplanes. Sales of completely new equipment, airplane, engines, instruments, propellers, and accessories, sold as a complete unit, and all above the cost of production, are unheard of for commercial work. We read of and see companies and individual flyers carrying passengers, but what company in America could afford to carry passengers if it had to pay the first cost of the airplanes and the engines. The Army patrols portions of the forests for fire protection, but no new airplanes have been sold to it or to individuals for that purpose. The Navy has done large-scale mapping, but neither the Navy nor civilians are buying new flying equipment for that purpose. The Post Office Department flies some mail, but has its own shops for rebuilding wartime DeHaviland airplanes and Liberty engines. The most discussed fields for commercial aviation are passenger carrying, photography, forest patrol and the transportation of mail and express. If in 5 years not a single complete American airplane has been sold above first cost for these purposes, for what commercial purpose shall we design either commercial airplanes or engines? We must find a market that can afford to purchase new equipment before we can design for that market.

Thus far, I believe we all shall agree that the impassable barriers to commercial aviation have been the cost and the lack of desire on the part of the public to fly often or at all. If we spread the cost very thin, and do not ask strangers to fly, does not the prospect look brighter? There is such a market ready and waiting, a market that will buy airplanes and engines eagerly as soon as they are proved to be better than the existing types. In this market any notable improvement that will increase the durability, economy or safety will find a ready sale. The requirements will be set forth so clearly that designers will be relieved from the present impossible situation of designing something for which there is no use or no sale. This market needs only to be told the story plainly and it will be sold, sold for all time, and will stay sold. This market is the people of the United States as represented in the biggest business on earth, the United States mail.

What the Aerial Mail Has Demonstrated

Facts and figures to prove this are abundant. The industry is immeasurably indebted to Congress for a continuance, during the last 4 years, of appropriations that have allowed the demonstration in an experimental way of two essential facts; that mail can be carried safely by air, and that it can be flown through winter weather in the North. This demonstration has been on a sufficiently large scale so that these facts cannot be disputed, in Congress or elsewhere. Another fact is the volume of mail to be carried, millions of letters daily that require no drumming-up of business. Still another is that the millions of special-delivery stamps sold yearly demonstrate that thousands of people are always in a great hurry to have their mail delivered, even though they know that special delivery means a saving of a very short time at the delivery end only. The volume of telegrams and night letters further proves this.

Here are more facts that have an important bearing. Carrying parcels by post costs millions of dollars more than the revenue received from postage, yet it was eagerly adopted and never will be discontinued. It costs more to deliver rural free-delivery mail from the local postoffice to the patron than the entire revenue developed at the point of origin amounts to, but who believes the rural free-delivery will be discontinued? As a final fact, the people, through their representatives in Congress, have been willing for decades to take a loss in carrying mail. This year it is predicted that the cost of the Post Office Department will exceed the revenue by about $60,000,000. If by air mail days can be saved instead of hours, if the revenue of the Post Office Department can

[1] Assistant to the president, Wright Aeronautical Corporation, Paterson, N. J.

be greatly increased and the operating deficit not materially increased, will more facts be required to get a market for our designers?

Let us scan some figures to substantiate these facts. Every day there is mailed in New York City for delivery in Chicago an average of 160,000 letters. But this, by no means, represents the full amount of first-class mail sent daily from New York City to Chicago. The average amount, I have been told, is about 25 tons, which is the equivalent of 2,000,000 letters per day, the difference representing gateway mail at both points and mail matter other than letters. Most of this mail leaves New York City after 5 p. m., and cannot be delivered under 30 hr. after the train leaves New York City, much of it being over 41 hr. on the way. To beat this time and to save a whole business day, New York City-Chicago mail must be flown all or part of the way at night. With proper beacon-lights and properly lighted emergency fields at, say, 20-mile intervals, with radio on the airplanes and radio-direction-finders on the ground, night-flying is possible.

We have prepared extensive estimates on the cost of equipping and operating a night-flying line from New York City to Chicago, based on the present known flying equipment, with the contractor providing his own fields, radio and lights. For four airplanes each way daily the cost will be less than $2,000,000 per year. These four airplanes would handle about 100,000,000 letters per year if they were carried all the way by air, or twice that number if carried part way by train and part way by air. But it is safe to assume that 150,000,000 letters per year between these two cities could be expedited 1 business day at a gross cost of $2,000,000, or about 1⅓ cents per letter. The Post Office Department estimates the present cost of handling a letter at about 1 cent; therefore, if the present cost of 1 cent were added to the air-transmittal cost of 1⅓ cents, the cost to the Government above the 2-cent rate would be only ⅓ cent per letter and the total cost to the Government would be only $500,000. It has been proposed by the Post Office Committee, for very good reasons, to charge a 6-cent rate for air mail and to make up the rest of the load with regular-rate mail matter. On this 6-cent rate there would be a profit to the Government of 3⅔ cents per letter; and 44,000 of these air stamps sold per day would yield sufficient profit to offset the $500,000 cost per year. Forty-four thousand letters are only about 2 per cent of the mail carried at present on this route. To prevent misunderstanding, let me repeat that this cost is based on four airplanes daily each way and a 4-year contract. The cost cannot exceed $500,000 and may be nothing. With two airplanes daily the cost would be about $1,500,000; with one airplane about $1,000,000 per year. The authorized rate to be paid to the contractor if such a thing were necessary, should be sufficient to cover the latter case, or 5 cents per cu. ft. of mail compartment space per mile. I do not think it would be necessary for Congress to specify a maximum or a minimum rate, because it has not done so in the appropriation for expediting foreign mail by air. It will be remembered that for years $150,000 per year has been appropriated for expediting foreign mail by air with no limit as to the rate.

The Effect on the Designer

This is where the rate begins to affect the designer. It probably would take 60 airplanes and 80 engines to cover the four-airplane route, as described above. Based on a 1000-hr. life, the airplanes would be worn-out in less than 3 years; so there would be a steady market for 20 airplanes and 27 engines per year on this one run. It is certain that if the New York City-Chicago route were established, other lines would be demanded and provided. The first extensions, perhaps, would be to St. Paul, Omaha, Kansas City and St. Louis, because all these cities could get the mail from New York City the day after it was posted, and would save 1 or 2 business days. Other probable routes would be two lines to the Pacific coast, one north-and-south line east of the Rocky Mountains, one from Chicago to New Orleans and one each on the Atlantic and the Pacific coasts. The total mileage might soon reach 15,000 miles, which would require from 500 to 600 airplanes, with a heavy yearly replacement of both airplanes and engines.

The design of airplanes for carrying mail from New York City to Chicago should be predicated on a mail-load of at least 1000 lb., a maximum speed of 125 m.p.h., and an economical cruising-speed of 100 m.p.h., with a fuel-capacity for not less than 350 miles. Forty letters weigh about 1 lb. and 1 cu. ft. of mail weighs about 25 lb., so that considerable weather-proofed cockpit space must be provided in a location that is free from fire hazard. A twin-engine airplane designed to fly well with one engine would, undoubtedly, be much more valuable for night-flying than a single-engine airplane. One such airplane was almost completed in Germany before work on it was ordered stopped by the Allied Commission. The improved vision of a twin-engine airplane, in that the pilot does not need to look through a propeller, almost equals in importance the added safety of such an airplane.

Passenger traffic would follow unsolicited as soon as the communities realized that the airplanes were flying safely and on-time. There would be little need of providing passenger space in mail airplanes, other than room for one passenger, perhaps, and that need not be made more comfortable than the pilot's seat. Mail airplanes will usually be loaded to their full capacity with mail and will leave at times and from places that may not be convenient for passengers. When passenger business comes, airplanes can be designed for it, but they will be as different from mail airplanes as Pullman cars are different from railway post-office cars.

Congress will not take action on this matter this term because of press of business. But at the next session plans should be made so that the matter can be presented clearly and forcefully. Not less important will be the presenting of facts to the people at large, so that they can understand what it will mean to them individually. So far as commercial aviation goes we have run round in circles for nearly 5 years. Here is a straight course. When the time comes to act, let us be able to depend on your support and efforts.

Service and Its Relation to the Industry

By Otis C. Funderburk[1]

Chicago Service Meeting Paper *Illustrated with* Drawings and Photographs

AFTER outlining the ideas regarding the success of a service-station which the author had when he entered the service industry, such as a convenient location and consistent newspaper advertising, the 24-hr. service that his organization is prepared to furnish for Ford cars is described briefly. The methods employed in getting service work on Lincoln cars by the use of circular and personal letters are commented on briefly, it being pointed out that January and February are now two of the best months in the year as regards the amount of service work performed instead of being dull. The importance of a modern tool-equipment and the careful selection of the personnel for a service-station are mentioned, emphasis being laid upon the fact that in a service organization the men should have a fundamental education for their work.

A number of pieces of special equipment that have been purchased from outside manufacturers or developed by the author's own organization are illustrated and described. Among the latter are an inclined platform for raising the front end of the car when work has to be done on the engine from underneath, a special spark-synchronizing device and a rig for relining brakes. The importance of having a thoroughly competent floor-man to meet the customer and write the repair order is emphasized; and a brief description of the method of handling work in the shop is given together with an outline of the road-test that is made of all jobs that necessitate any change in the running-gear of the engine. The importance of delivering the car to the owner on time, clean and free from tool-marks is pointed out.

The flat-rate system of service charges receives consideration, the author being of the opinion that eventually practically all maintenance work will be handled on that basis. The way in which the flat rates charged by his service-station were arrived at are outlined briefly. An indication of the way in which cost data on an operation are secured and distributed among the various accounts completes the paper.

SERVICE is to the automobile business what safety-vaults are to the banker. Both are essential to the security of the business. Today we have graduated the industry into the greater realm known as "transportation service." This embraces rail, electric and steamer lines and motor cars and trucks. The motor car is now sold as much by the satisfactory reputation of the service-station of the dealer as by the efforts of the sales force. One of the first questions asked by a prospective customer is, "What kind of service do you give?" Service should be founded upon a mutual understanding based on honesty.

When we started our business we had certain ideas which have proved successful. First was a convenient location. We therefore built upon a corner of the most prominent thoroughfare in Boston, Commonwealth Avenue, which is in the heart of the automobile district. It was more costly but it has more than repaid us in advertising value, as well as proved a great aid in sales and service. Our firm was made up of practical executives who had had extensive experience in dealing with owners of high-grade motor cars, and we aimed to make service an asset and not a liability. From the start we were firm believers in advertising and used the newspapers consistently. We made an analysis of circulations. Our new building was fitted up so that it was not outranked by any other in the city. An electric sign on the roof that could be seen for miles in all directions flashed the name Lincoln every few seconds. It now flashes both Lincoln and Ford names and the fact that we give 24-hr. service on Ford cars.

We decided to follow right through with the owner in a service way from the very day he took delivery of his car, our first step in this direction being to attach a small tag to the instrument-board regarding the changing of oil and grease, the care of the battery, etc. In view of the fact that we had a new account we felt that a large proportion of our service work at first would come as a result of accidents to customers' cars. Our plan for taking care of cars that have been in collisions is efficient without involving brass-band methods. Instead of a service-vehicle painted in bright hue, with machinery and tackle like those on a wrecking train on a railroad, we send out two cars. The owner with his family transfers into the first one and goes away from an embarrassing predicament, and the wrecked car is towed quickly and quietly to the service-station. We have found that our owners appreciate this spirit of co-operation on our part.

24-Hr. Service on Ford Cars

When we took on the Ford account we inaugurated our 24-hr. service for Ford cars. This has proved very successful. Owners of fleets, especially, realize how much it means to know that they may have any disabled car brought in at night for repairs, and have it back on the job the next day unless too badly damaged to make this possible. This has not only brought us much service work but also many sales. The police departments of a number of the cities and towns adjoining Boston now telephone us when a car is disabled or abandoned and ask us to come out and remove it from the highway, no matter what make of car it may be. We find now that five men can operate the night shift. In an emergency they can make up two wrecking-crews, leaving one man in charge of the shop; and when not on the road they can take care of an extremely large amount of repair work. The percentage of towing jobs are 35 per cent at night and 65 per cent by day.

Our method of getting work into our shop has, perhaps, been rather unusual, especially in connection with the Ford service. Shortly after we started handling Ford cars, we made an investigation and found that we were not getting much repair-work, this being due to the fact that the Ford business in and around Boston is extremely well organized and it is rather difficult for a new-comer to break into the service work. We therefore secured a list of Ford owners in greater Boston and to some 25,000 of these we issued a card very similar to that given by a club to a member. The owner's

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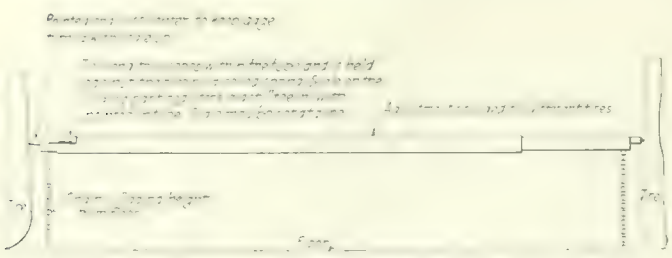

Fig. 1—Front-Wheel Gage That Is Adjustable for Various Sizes of Tire

name was written on the card which stated that he was entitled to inspection and adjustment of the ignition system on his car at 30-day intervals, for which no labor charge would be made. On one side of the card was an illustration of our building, the 24-hr. service being featured. Above this engraving was a place for entering the dates of inspection. The results were surprising. Many Ford owners called to look our building over, some coming at night because that was their only available time. Very soon the word went around that here was a place to get something done at any time and gratis if warranted. To give actual figures, an average of 25 owners a day called at our Ford repair-department in the first two months. Many asked questions about ignition which were answered courteously and thoroughly. A large number bought coil-points, generator cut-outs, timer parts and similar supplies. Most of them are now permanent customers. We have sold 30 or 35 new Ford cars in this way; and all of these sales will aid us in building up our Ford business.

In connection with getting service work on Lincoln cars, we have kept in touch with our owners by circular and personal letters. About the middle of October, we send out a circular letter stating the percentage of alcohol to obtain a proper anti-freeze solution and advising owners what our charge will be for it. When the tail-lamp regulation went into effect in Massachusetts we went to the trouble of having a specially designed bracket made to attach a high-grade tail-lamp to Lincoln cars. We then sent out a circular letter to all Lincoln owners, and as a result attached tail-lamps to approximately 80 per cent of the Lincoln cars in Massachusetts, despite the fact that some 30 or 35 lights were being marketed at a lower price than the one which we offered. This was striking evidence of the fact that owners of high-grade cars are not penurious when it comes to buying something really good for their cars. About the middle of December, we send out a circular letter to all our owners telling them that the best time has arrived for overhauling and repainting their cars. This enables us to get in a large amount of work during the period which is usually dull, and, due to the good profit in repaint work, January and February stand out as two of the best months in the year as regards the amount of service work performed. As we have no paintshop of our own we job the work out to two or three shops near by at wholesale prices. When we notice on a customer's service card that he has not had his car in the shop for some time, we either write him a letter or get in touch with him personally to find out if he is dissatisfied. This is very rare, however, as upon the completion of a service job we usually write the owner asking him if the work has been performed satisfactorily and if he has any comments to make. If there are any criticisms or misunderstandings they are straightened out without delay.

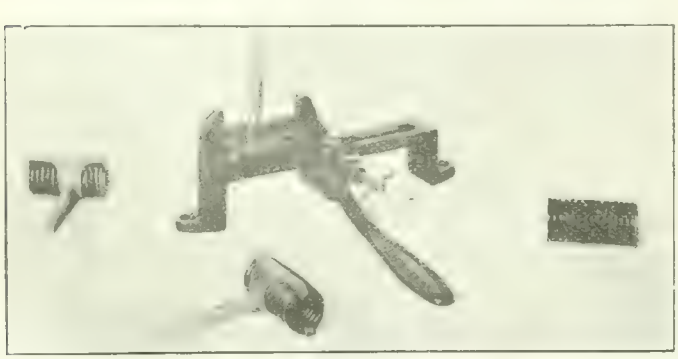

Fig. 2—Device for Compressing Valve-Springs

Modern Equipment and Trained Personnel Necessary

After getting the work into the shop, it is up to us to see that it is performed in accordance with our policies as set forth in the preceding paragraphs. This means that our equipment must be thoroughly modern and that our workmen must be efficient and well-trained. Of course, the small dealer in the little town cannot carry 100 per cent tools and machinery, but he should be sold on the idea that no chain is stronger than its weakest link; that slipshod methods in the smaller towns eventually will reflect upon the distributor, and through him on the maker, thereby lessening sales at a cost to all concerned. The distributor should keep in close touch with the outside dealers to aid them when service problems come up; not in a patronizing way, but with a spirit of cooperation. The small dealer may be able to give the distributor ideas; coordination will build up the entire organization. When the service everywhere, or nearly everywhere, is uniformly good it becomes known to each owner through other owners, and the owner then begins to take an interest in his car, so that the chauffeur will not be allowed to take a car to some friend to have it repaired. It is one of the best methods to get the work inside your doors.

The personnel should be selected carefully. It cannot be done in a week or a month. In our organization we have been building up the personnel from the start. We treat our men in such a manner as to give them a feeling of trust and confidence. We do not jump on them when they make a mistake. They have been taught to know that mistakes are costly; that they may be avoided by using common-sense and judgment; that it is better to prevent them at the start. So our workers are not afraid to ask questions or let some one know they are puzzled by a certain bit of work. This has been brought about by asking men to rectify mistakes they have made by working at night without pay. They have agreed that this is fair and do it without grumbling. But the men learned their lessons so long ago that we have minimized mistakes now. This has resulted in eliminating that bugbear of service departments, concealed mistakes.

This is the age of specialists. Therefore, in a service organization the men should have a fundamental education for their work. On our ignition jobs we put men who have been educated in the underlying principles of electricity. Other men do all their work on transmissions. Various other parts of the car are taken care of by men who have developed for just those things. This leads to efficiency. When the ignition man has a magneto to take down, being skilled, he goes to the tool-rack and picks out proper wrenches, screw-drivers and other tools needed for the job. The unskilled man takes a couple offhand, goes back to his bench and tries them; they may not fit, and he makes a second, third or fourth

trip, mentally guessing what he needs. That means just so much more time that the owner is paying for; waste time in getting the repairs done as specified. The same applies to other jobs. In our service department we have overcome this through talks to the men, and also by having experts come in to show what can be done through systematic effort. The results accomplished in this way have been extremely satisfactory as the men take pride in the efficiency with which they do their work.

It is a fact that work cannot be efficiently done without the proper tools. The manufacture of labor-saving devices for automotive work has become a complete industry in itself. There is no excuse for any service-shop trying to get along without the proper equipment. For a small extra charge we had a representative of a large socket-wrench firm call and design wrenches for us that would fit the various jobs. For instance, they furnished a double-end Ell wrench that fits both the cylinder-head and the intake-manifold nuts. This type of wrench which cuts down the number of tools a worker has on the job is invaluable as a time-saver, yet its cost is trifling. Precision tools also have become familiar to us and are a necessity. Pistons, crankshafts and cylinders cannot be properly inspected without micrometers. Crankshafts or connecting-rod bearings cannot be tested for eccentricity without an indicator gage and the proper clamps for holding it in the various places of application. This sort of equipment assists a worker in immediately locating the source of trouble. How could the noise in a tappet due to a flat spot in a cam roller be located without accurate measuring devices? Builders of motor cars generally are able to supply the service-man with a good line of special wrenches, pullers and other tools which are of great value.

Some Special Equipment

Out of all the various duplications of devices by different manufacturers, there is generally one that appears to be so much better as to make the sales success of any of the others seem a mystery. Such a device is a front-wheel gage illustrated in Fig. 1 which is manufactured near Boston by a small company. The ingenious manner in which the complicated process is performed accurately has made this gage very popular with local service-men. When this gage is in use it is placed between the front wheels on the forward side of the axle with the pointed ends bearing against the tires and the pendant chains with their ends just touching the floor. Both ends are telescopic, one being adjusted and set for the various sizes of tire and the other being forced outward by a coil spring inside the bar. The tension of this spring and the pointed ends are sufficient to hold the gage in position. The sliding end carries a graduated scale that is adjustable and can be set at zero after the gage is in place. The pointed ends being off center, the scale is always on the upper side where it can be easily seen. After this gage is in place the car is rolled forward until the gage is behind the axle and the chains again have their ends just touching the floor. The toe-in is then read from the scale. This reading is accurate regardless of irregularities in tire mounting and untrue wheels because the gage is not moved between readings.

Another device that is a great time-saver and makes a dangerous operation safe for the worker is the valve-spring compressor that is illustrated in Fig. 2. Everyone who has worked on engines has a dread of placing a valve-spring in a vise together with two little blocks and then fitting a pair of clips to hold it while putting it in position. The equipment pictured here compresses the spring with an ingenious lever and toggle arrangement and the double clip with the handle is absolutely safe against slipping. Complete sets of these clips on the job eliminate unnecessary trips by the mechanic between the car and the spring compressor which is screwed to the bench. This rigging has found great favor with our mechanics.

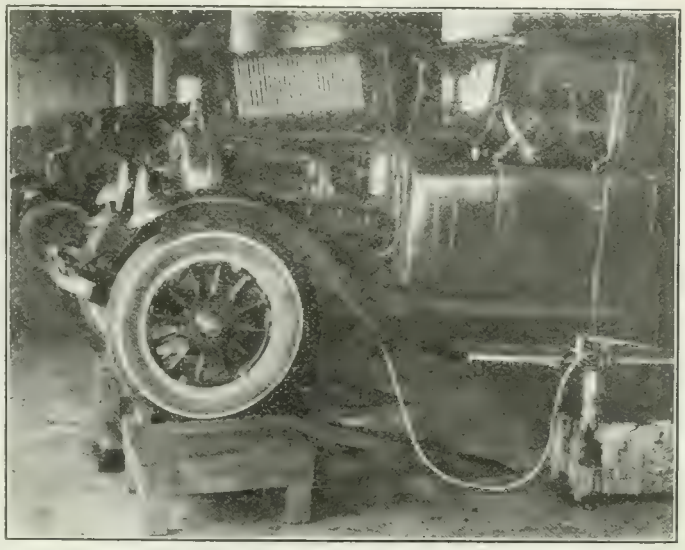

Fig. 3—One of the Inclined Platforms That Has Been Developed To Raise One End of a Car Clear of the Floor and Permit a Man to Work Underneath

In Fig. 3 will be noticed a large floor-type Alemite gun. With the use of this gun we are able to grease a car in less than half the time necessary with a hand-gun. Referring to the photograph, a stroke of the lever, which is seen in a horizontal position on top of the container, forces into the part to be lubricated ½ cu. in. or so of grease under pressure as high as 2500 lb. Additional pressure is applied only on the lever and is not stored up in any way. This is a great advantage over the screw type of hand-gun that must first be screwed up to apply

Fig. 4—Diagram of the Spark-Synchronizing Device

the pressure and then unscrewed before disconnecting the hose.

We maintain a small engineering office in which development and advancement work is carried on. When the need of some device is felt and there is nothing in the market to cover the work, equipment designed to meet the approval of those concerned is built. Such a product is the spark synchronizing device for the Delco ignition system on a Lincoln car which is arranged with a separate breaker for each bank of four cylinders. One of the adjustments which is most important to the performance of the car and one of the most difficult to make exactly right is the synchronizing of these two breakers. The spark must have exactly the same advance in both sides of the engine. Referring to the diagram that is reproduced in Fig. 4, the breakers are located on the posts at *a* which are fastened to the base plate. The base plate in turn is fastened to the distributor main casting with three screws. These screws at *b* pass through a slot in the plate that permits the whole plate assembly to oscillate about the third screw at *c*. This oscillation changes the angular relation of the two breakers and permits of an accurate synchronization. Our method of making this adjustment is very simple and very accurate. After removing the distributor head and rotor the pointer shown at *d* is slipped over the cam and a pencil mark on the distributor casting is made opposite the pointer wherever it should happen to be. The protractor, which has a pilot on the under side fitting the casting bore, is laid in position on top of the distributor casting and the screw that spreads the shaft inside the cam is loosened. The pointer may now be revolved freely about the shaft without turning the engine over. A small light on a dry-cell circuit is wired to each breaker so that the light goes out when the contacts break. The Lincoln cylinders being spaced on an included angle of 60 deg. the pointer should travel 30 deg. from the first spark to the second and 60 deg. from the second to the third. The protractor is graduated every 30 deg. and shows the permissible tolerance of 2 deg. in either direction. We find that if the points are smooth and the gap properly adjusted and the break occurs within the tolerance but not exactly on the exact point it can be corrected by slightly adjusting the gap but if the break occurs more than 2 deg. off it is necessary to change the position of the plate. It will be noticed that this is also a check on the workmanship of the cam and makes it possible to set these breakers to give the best results in all eight cylinders, in place of adjusting from two adjacent cylinder markings on the flywheel. After this adjustment is made the cam set-screw is tightened, locating the pointer from the pencil mark on the casting, and the distributor is reassembled. The use of this device is obviously a great time-saver over the old method of taking up the floor and the clutch cover and adjusting from the marks on the flywheel while turning the engine over by hand. It is also seen that it is vastly more accurate when account is taken of the lag in the timing chain and of the tolerances adding up in the many parts that form the drive between the crankshaft and the distributor. Fig. 5 shows the general layout of this device, the wooden box carrying the dry cells and the pair of small lights in their protecting cage.

Fig. 5—The Spark-Synchronizing Device in Use on a Car with the Dry Cells and the Pair of Indicating Lights Above

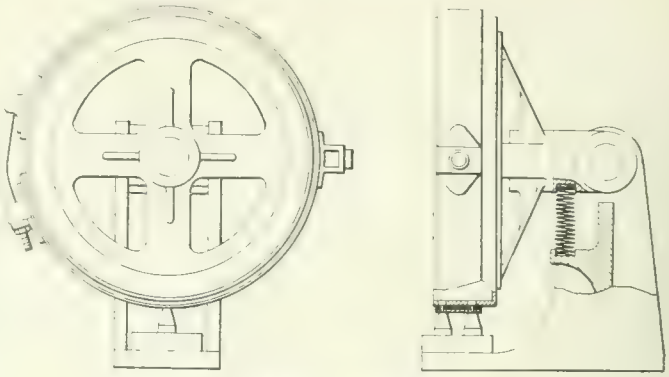

Fig. 6—Jig for Relining Brakes

Relining brakes has always been a mean job. It is very difficult to hold at one time the band, the lining, the small rivet and the punch. This process is common enough to merit a business-like and efficient rig. The sketch reproduced in Fig. 6 shows the stand that is bolted to the bench and the method of mounting a brake-drum on a shaft so that it can be turned about its center and also raised off the dies. The band and the new lining are placed on the outside of the drum and tightened into place. A ½-in. hole located at each rivet in the drum permits all the holes in the new lining to be drilled at one time. The tubular rivets, which we have found entirely satisfactory, are all pushed into place and then riveted from the inside of the drum, through the series of holes, using the dies to hold the rivet-head. The coiled spring is adjusted so that it is capable of just balancing the weight of the drum assembly. The weight of the punch in the worker's hand easily holds the rivets down to the dies but, upon releasing, the coiled spring forces it up to a position where all the irregularities on the band clear the die and the drum can be revolved on its shaft. This method has worked out very well and made it possible to reline a brake in less than one-half the time consumed when using a vise.

We have found that chain-falls mounted on a rail are far in advance of any portable jacks and hoists. They can be used for removing the body, the engine or the rear end. We hoist the front end of the engine for timing work in place of jacking up from underneath. It is necessary, however, when doing piston or bearing work from the underside to have the car very steady. The swinging resulting from chain-falls retards the use of indicator gages and other measuring tools. For this work we made up the inclined platforms shown in Fig. 3. They are of exactly the right height to permit a man to work comfortably on a floor-creeper and yet they in no way inconvenience him. The car can be driven on and off of these platforms without difficulty.

We have always instructed our men to be very careful not to mar or spot the cars. The photograph reproduced in Fig. 7 shows how carefully cars are covered while they are in the shop. Note that even the steering-wheel and the front frame-bar are enclosed in leather wrappings. The men are furnished with clean overalls daily.

FIG. 7—HOW CARS ARE COVERED WHILE THEY ARE IN THE SHOP

Not responsible for articles left in cars or fire flood or other causes beyond our control

REPAIR ORDER

FUNDERBURK & MITCHELL, Inc.

1001 COMMONWEALTH AVE., BOSTON, MASS.

L5266

Serial Number

PARTS USED

Qnan. Part No. Name Price

Promised Date 192

Owner's Name

Phone

Address

Lic. No. Car No. Mileage Deliver to

Wash and Polish

Change Oil

Alemite

Adjust Chain

Test and Adjust

Workman

Parts Supplied As Necessary

Total Parts

MATERIAL

gals. Gasoline

qts Oil

lbs Grease

Total Material

LABOR

Hours @ per hour

Total Labor

Total Charges

Authorized by

Received by

FIG. 8—FRONT OF THE ORIGINAL COPY OF THE REPAIR ORDER WHICH IS MADE OUT IN TRIPLICATE

CAR RECEIVED

WORK COMPLETED

Shop Inspected by

Remarks

Road Tested by

Remarks

Work done as per instructions and delivered to

Released by

FIG. 9—BACK OF THE TRIPLICATE OR SHOP COPY OF THE REPAIR ORDER

The cover on the front-seat upholstery remains on the car until all testing has been accomplished. We believe that much of the success attained by many automobile service-stations can be traced directly to the fact that they are properly equipped. We find in our own particular organization that courtesy in its broadest sense has more to do with the satisfaction of customers with our service than almost any one other item. The average customer is so accustomed to short, curt replies, indifference and impoliteness that when he is faced with a courteous service-man he immediately thaws out and becomes the regular fellow that he really is underneath.

By far the greater majority of complaints regarding poor service result from misunderstandings between the customer and the service department. The logical time to prevent these misunderstandings is when the car is first brought to the service-station and the order written. One of the most responsible positions in the service department is that of the floor-man who meets the customer and attends to his wants. This man must have a pleasing personality, a neat appearance and, above all, he must know the car thoroughly. He must be a trained mechanic, electrician and tester and, if his work is properly done, misunderstandings and complaints very, very seldom arise. We aim, first, to listen attentively to the customer's story of his difficulties, either real or imaginary, and then make a careful analysis of these difficulties to the end that the repair order when written shall give the shop superintendent very definite instructions that will enable him to perform the work so that it will be exactly what the customer desires to have done, if that is possible.

Handling Work in the Shop

Our repair order, a copy of which is reproduced in Fig. 8, is in triplicate form. The original copy remains in the order office, the duplicate is given to the customer and the triplicate copy, which is of heavy cardboard, follows the car until all of the work is completed. This order contains all necessary information regarding the customer; such as his name, address and telephone number; the type of car, its mileage, factory and registration numbers and anything that may be needed for future reference. Certain printed notations call the customer's attention to work that in many cases might otherwise be forgotten. The customer, of course, is required to sign this order upon leaving the car. When the car arrives in the shop, the repair order is time-stamped on the back, Fig. 9, and turned over to the shop superintendent. Spaces are provided for signatures of inspector and road-tester and the man who delivers the car. When the work is completed the card is again time-stamped and returned to the billing office together with time-slips and stock requisitions issued against the particular order, in order that the job may be billed and ready when the customer calls. Thus, some particular man is made responsible for each step the car goes through, from the moment it arrives at the service-station until it is delivered to the owner. Under no conditions is any employe permitted to make any misrepresentations to the customer regarding the condition of his car and we take especial care, even in cases where an estimate of the cost is not requested, that the customer be given at least a general idea of the probable expense involved. We endeavor to make all estimates sufficiently high so that we shall be able to give the man as much as or more than we promise for his money. Dissatisfied customers and long overdue accounts often are directly traceable to neglect on the part of a service department to give an owner full information regarding this point.

It is very important that all work be thoroughly gone over by a well trained inspector, in addition to the supervision of the shop foreman. A great many motor cars are not performing correctly due perhaps to the need of a single adjustment that an experienced trouble-man would immediately set right. A road test is included in the work called for on every job that involves any change in the running-gear or in the engine. Our road tester is one of our very best men. To discover if a car's performance is up to average it is necessary to adopt some sort of a standard test and get comparative results. Each car that is road-tested is run over a selected road-test hill and its performance carefully checked up. The cars are started up the hill at 5 m.p.h. and at a given mark both the throttle and the spark are advanced fully. A car that is in good condition will take this load smoothly and slowly accelerate. Faulty ignition or leaky valves are indicated at this point by bucking or skipping. Too great a spark-advance or a carbon deposit is noted by clinking or knocking. Poor carburetion due to faulty setting, improper float level or a clogged line immediately becomes evident. If a car has performed well up the entire hill and passes a mark at the top at a speed of 29 m.p.h. for heavy closed cars or 33 m.p.h. for the open models it is pronounced in good adjustment so far as power is concerned. If its performance has been under the average, the tester, by the process of elimination and by repeated runs up the hill, locates the trouble and makes the adjustment on the road. If the trouble is such that it is necessary to install new parts or to do costly work not called for on the repair order, the inspector writes a full account of his recommendations on the work card. The service foreman then telephones to the owner for permission to do the work.

The upholstery in the cars is examined and cleaned just before delivery to the owner, and the steering-wheel is carefully cleaned. The necessity for this care in inspecting can readily be seen by observing the owner who drives away untroubled and the one who is bothered with petty annoyances. Imagine the feelings of the owner whose gloves are spotted with grease from the steering-wheel or whose car behaves better in some respects and worse in others. Too much attention cannot be paid to the inspection department; the cost will be easily returned in the good-will of customers who become permanent boosters.

All particular customers are not cranks. It is an admirable trait in a man to have a great pride in the ownership of a fine car and to wish to keep it in as perfect condition as possible. He is well justified in objecting to nicked rims and scratched paint on the wheels due to careless tire-changing. He is not at all unreasonable in his aversion to chewed-up screw-heads on the battery cover, or plier marks on the windshield adjusting nuts. He rightly feels that, as he is extremely careful of his own property, there is no reason why he should pay to have someone else mar it. We have one owner who comes in periodically to have his engine cleaned. After the first cleaning job, he explained rather indignantly that he wanted the engine to look as nearly like new as possible. If parts had to be removed and polished and it had to be gone over with a small brush and gasoline, he wanted it done, as cost was absolutely no object. He has since paid several fairly large bills for this kind of work, and we have never had any further trouble with him in this connection. He was simply an example of the customer who wants things done in absolutely A-1 shape and is willing to pay for it.

Flat-Rate System

The flat-rate system of service charges is becoming more and more popular with owners as well as service-stations. We believe that eventually practically all work will be reduced to this basis. Experience and careful cost systems will consequently reduce all operations to a basis that will be entirely satisfactory to the customer and provide a reasonable profit to the service-station, at the same time making business relations much more agreeable to all concerned.

Our flat rates were established only after a careful analysis of very many jobs covering a considerable period of time, and in every case our repair order shows by whom the work was performed and the exact amount of time consumed. We are thus able to determine which of our employes is most efficient in any particular line of work and compare his average time with that of the others. We base our charges, however, on the average time for a given number of similar jobs, and then if we are able by consistently using certain efficient men in any particular line to reduce this time, the shop receives the benefit. So far as possible we endeavor to keep each man in some particular line of work as he rapidly acquires a degree of efficiency that he could not otherwise attain. We allow him the greatest freedom in offering suggestions as to methods that will improve the quality of his work as well as the speed with which it is performed. We endeavor to assist him so far as possible with the best of equipment and special tools, making a study of each particular operation to eliminate all unnecessary movements.

For instance, the adjusting of connecting-rod bearings is usually a rather uncomfortable and slow operation, but by applying the above-mentioned methods we have been able to cut the time consumed approximately in half and at the same time turn out far better work. The car is first elevated in front by running it up onto a wedge-shaped incline, and the oil drained. The removal of the oil sump, which is usually a rather dirty job, is done by helpers with high-speed wrenches, and any surplus oil removed from the exposed parts. The man who actually does the adjusting is one thoroughly skilled in his work and he is supplied with special racks and a crate in which he has every tool required for the operation and a place to lay all the parts that it will be necessary to remove while the operation is being performed. Thus, when he once takes his position under the car, it is never necessary for him to come out until the work is completed. We find that with this comparatively simple equipment the men rapidly take a greater interest in their work and in the speed with which it can be performed. But in no case do we ever risk quality for speed. This same procedure has been carried out in connection with every other operation on which we could possibly establish a flat rate and has proved very satisfactory and profitable.

Securing Cost Data

In addition to the customary time-clock record, our workmen are all required to keep a day card, a portion of which is reproduced in Fig. 10, on which they record the various jobs on which they work during the day, accounting for every minute of their time. These cards are tabulated each day by one man whose duty it is to segregate each man's time into the proper divisions, recording it under the following 17 headings used in the distribution of all labor:

(1) Productive Labor
(2) New Car

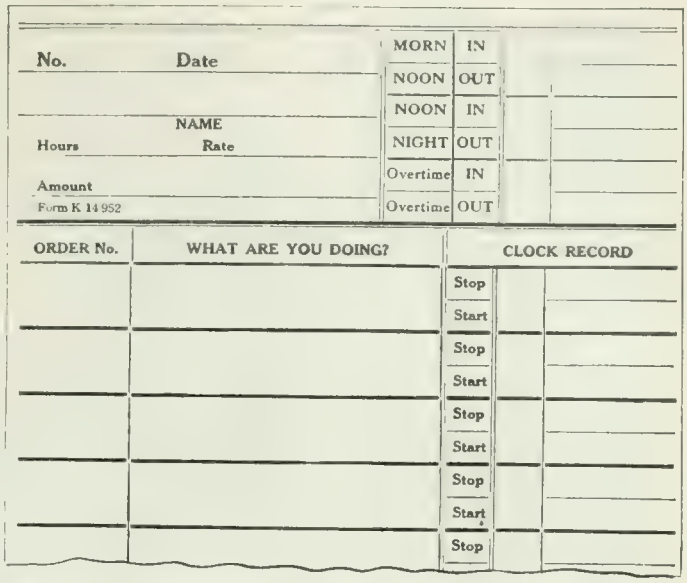

Fig. 10.—The Workman's Day Card on Which He Keeps a Record of the Various Jobs Worked on during the Day

(3) New-Car Service
(4) Used Car
(5) Used-Car Service
(6) Shop Labor
(7) Stock Room
(8) Garage Labor
(9) Lost Time
(10) Guaranteed Work
(11) Company Business
(12) Chauffeur
(13) Maintenance of Building
(14) Maintenance of Demonstrating Car
(15) Maintenance of Company Car
(16) Maintenance of Official Car
(17) Tractor Department

At the end of the week this time is reduced to cost and the cost classified on a large sheet that permits us to determine at a glance the exact cost to us for the labor consumed during the week in each of these 17 departments. We are thus in a position to check up very closely on what is going on in our service department, to reduce as far as possible our non-productive labor and to increase the efficiency of the men. By the use of these sheets we were enabled during the first three weeks to increase our productive labor 5⅓ per cent and, at the same time, decrease our percentage of non-productive labor 5⅔ per cent. We are hopeful of some very fine results from this system after it shall have been in operation a greater period of time. This system is kept so accurately that the accounting department can use it for making all charges to the new-car department, used-car department, officials and other accounts, and from it we obtain an absolute record of each man's time during the week and get very valuable information regarding the efficiency of the individual.

The time is coming when there must be a complete understanding in every automobile organization between the sales and the service departments. The salesman will have to learn some of the elements of service; what it is, what the service department is capable of doing and what its limitations are. The salesman will not be allowed to hide behind false excuses when a customer demands that a verbal contract made when he bought the car be lived up to.

There shall be coordination all along the line from the

maker to the helper in the service-station. We have striking examples of how service may be impaired through lack of this element in the way railroads are operating today as a result of shopmen leaving their work, or not doing it properly when the men are disgruntled. Transportation broke down.

The motor-car industry is furnishing a means of transportation that in many ways is supplanting the railroads. This is increasingly evident year by year. The industry has grown to tremendous proportions because of this fact. It must continue to grow. But it cannot grow adequately if there is any impediment in its path, and the one big impediment that could stop its progress is lack of service. We have been growing too fast to realize this until now. It is time we faced the proposition squarely. Let us build our industry upon satisfactory service. It will prove a foundation that will enable us to reap the rewards to which we are entitled for furnishing mankind a means of bridging distance and multiplying the value of his waking hours, a thing whose worth it is impossible to measure in dollars and cents.

Standardized Mental Test in Personnel Selection[1]

By Dr. W. V. Bingham[2]

A ROUGH measure of the brightness, or mental alertness, of an applicant, by a standardized mental test, has long been recognized as one of many possible sources of information for use in personnel selection. Early tentative attempts to use this test technique in employment procedure sometimes met with anomalous results because it was not recognized that, for some types of employment at least, an applicant may be too intelligent.

In affiliation with the Carnegie Institute of Technology, Pittsburgh, a group of 27 companies of national scope established, in June, 1916, the Bureau of Salesmanship Research, now the Bureau of Personnel Research. This Bureau was to pool the experience of the cooperators to evaluate their current procedures and to devise and try-out new ways of selecting and developing salesmen. The first year's work, under Walter Dill Scott, was issued in a volume of Aids in Selecting Salesmen that included an improved personal-history record, or application form, a model letter of reference to former employers, a guide to interviewing that helped the interviewer to focus his attention on essential traits and to record his judgments quantitatively,[3] and a set of five psychological tests with full directions for giving and scoring.

Among these tests was a group intelligence examination, a forerunner of Army Alpha. It was given to various groups of salesmen and sales applicants, and their scores were checked against actual success as measured by amount of sales. Among the men so examined was a group of 40 salesmen for a food products company. To the dismay of the research workers, when the intelligence-test scores were compared with the men's sales-production records, the correlation was almost zero. This appeared to be a severe indictment of the test as a measure of intelligence.

Then came the war, and with it a vast experience in personnel classification and intelligence examining. The psychological tests proved their worth in the Army as indicators of mental alertness. So when C. S. Yoakum, with this background of Army experience, in 1919, assumed direction of the Bureau of Personnel Research, he knew that the intelligence-test methods were valid, and he sought another explanation of the riddle in the findings of 1916. Taking the same data, he computed the correlation between test scores and length of experience with the company. The correlation was not zero. It was negative, —40. The brighter the salesman, the quicker, as a general rule, he left the employ of that firm.

Mr. Yoakum repeated the experiment with 76 salesmen of this same company, using the best available adult intelligence examination. The correlation of test scores and length of experience was 46. A job analysis revealed that the work was largely of the routine, order-taking sort. The pay was not large. Chances of promotion were slight. Only the more stolid men were content to remain long enough to get valuable experience and build up a creditable sales record.

Examining the intelligence scores again, it was apparent that there is an upper limit as well as an anticipated lower limit. Within this range, the chances are large that an applicant for a position with this company will make good. Below this zone he will probably fail for lack of ability. Above it, the probabilities are that he will not remain long enough to learn his work thoroughly and make a good showing. The psychological test had, after all, been a valid measure of mental alertness. The need had been for a determination of its range of utility.

This range varies for different kinds of salesmen, as well as for different occupations. In many jobs it has been shown that there is no upper limit to the optimum intelligence score; but studies of policemen, salesmen and many types of operatives and clerical workers, where the task is essentially routine, have shown how necessary it is to keep an eye on the upper as well as the lower critical score. Research on the utility of psychological methods in employment and placement is but one of many scientific approaches to problems of industrial personnel. Taken as a whole, the scientific study of the human factor may prove as important to the next era of industrial progress as research in the physical sciences has proved hitherto.

[1] Issued by the Engineering Foundation.

[2] Director of cooperative research, Carnegie Institute of Technology, Pittsburgh.

[3] This form later became the Scott Rating Scale of the Army.

TRAFFIC

A SAVAGE can travel after a fashion in a jungle. Civilized activity is too complex to be carried on without smooth roads. It requires signals and junction points; traffic authorities and means of easy and rapid transportation. The eternal dignity of labor and art lies in their effecting that permanent reshaping of environment which is the substantial foundation of future security and progress.—John Dewey.

Proper Utilization of Natural Gasoline

By Lloyd F. Bayer[1]

Annual Meeting Paper

THE term "natural gasoline" has been accepted generally by the petroleum industry as applying to the gasoline product extracted by any process from natural gas. Two processes are in use. The older one is the compression process applied to casinghead gas, which is produced from the oil-bearing sands of oil wells and carries vapors from the oil with which it has been in contact. This process of subjecting the relatively rich gas to a high pressure and then cooling it to or below atmospheric pressure, results in the direct condensation of gasoline which is weathered later to remove the "wild" unusable vapors.

The later method is the absorption process in which the gas is brought into contact with a heavy oil, originally of no gasoline-content, which absorbs the gasoline. The enriched oil is then heated to distill-off the gasoline, and these two operations of absorption and distillation are repeated continuously within a closed system.

The author discusses the proper usage of natural gasoline in blended fuels as determined by a lengthy series of tests.

THE problem of securing the largest possible supply of the best possible motor-fuel is before the petroleum industry. It is a problem so intimately connected with the problems of automotive power and engine design that it can be said to be a joint problem with the automotive industry. Certainly the petroleum industry cannot expect to supply motor-fuel, in the quantity production that it is being called upon for, without due regard for the problems of fuel economy and life of the engine. On the other hand, the automotive industry cannot say, without regard for the element of quantity production, that it must be supplied with a fuel uniform in quality and having none of the, from its standpoint, objectionable properties that have characterized some of the motor-fuel of the past few years. This fuel has been put out by the petroleum industry in its effort to meet the constantly increasing quantity demand. A medium quality will prevail between the present so-called superior and inferior grades now being manufactured, with the ever-increasing necessity of decreasing the quality to increase the quantity. With both industries coordinating their efforts, that is, by each working with a knowledge of the other's problems, a happy medium can be reached; otherwise, at least, it will be an unhappy medium for one of the industries, and surely for the consumer.

Natural gasoline is destined to play an important part in the solution of this problem. As to a definition of this product, following the organization of the Association of Natural Gasoline Manufacturers, in the Middle West, the term "natural gasoline" was adopted by it and has since been accepted generally by the petroleum industry to apply to the gasoline product, extracted by any process, from natural gas.

"Natural Gasoline" Processes

In general, without taking account of the myriad of varying details, two processes are in use. The older one is the compression process applied to casinghead gas, that is produced from the oil-bearing sands of oil wells and that carries gasoline vapors from the oil with which it has been in contact, thus giving rise to the term "casinghead gasoline." This process of subjecting the relatively rich gas to a high pressure and subsequently cooling it to or below atmospheric temperature, results in the direct condensation of gasoline that is weathered later to remove the "wild" unusual vapors. The later method is the absorption process in which the gas is brought into contact with a heavy oil, originally of no gasoline-content, that absorbs the gasoline. The enriched oil is then heated to distill off the gasoline. These two operations of absorption and distillation are repeated continuously within a closed system. This process was first applied to the natural gas transported through pipe-lines for commercial and domestic use. This gas was very lean in gasoline content. The process has since been developed to the point where it is now rapidly displacing the compression method for all kinds of both lean and rich gas.

With the production of automobiles and the consumption of gasoline mounting at a rapid rate, and our domestice sources of crude oil being increasingly drawn upon, the necessity is apparent for obtaining more gallons of gasoline from each barrel of crude oil produced. The refiner and his staff of experts are constantly devising and perfecting means of making more gasoline from the crude oil. They are accomplishing this, first, by a sharper separation of the fractions cut from the crude; second, by the installation and operation of cracking processes designed to convert substantial proportions of gas oil, fuel oil, or heavy distillate, to gasoline similar in general characteristics to that produced directly by distillation; and, third, by the use of natural gasoline, to render sufficiently volatile for satisfactory gasoline certain fractions of the crude that, of themselves, would not meet the requirements of an acceptable grade of motor-fuel.

It is to this third phase that I direct attention, developing the subject less from the refiners' and natural gasoline manufacturers' point of view than from that of the automotive engineer and the automobile user. The interests of the consuming public in utilizing natural gasoline can be served best by using a relatively uniform percentage of this product in all the motor-fuel consumed during a given season of the year, and varying this percentage to meet the varying demands of the different seasons. This is, of course, a general statement. The required percentage is subject to variation due to the inherent characteristics of the gasoline cut from the crude oils and to varying climatic requirements of different sections of the country.

Usage of Natural Gasoline

With all motor-fuels, particularly those of higher end-points, it is desirable to increase the percentage of natural gasoline used in the winter over that used in the summer to assure the greater volatility necessary. Although the consumption of gasoline is considerably less in the winter than in the summer, and the production of natural gasoline slightly greater in the winter, it is both practicable and desirable from the point of view of the gasoline manufacturer, the refiner and the consumer, that the percentage of natural gasoline in motor-

[1] Chief engineer, Tidal Refining Co., Tulsa, Okla.

fuel be increased sufficiently during cold weather to utilize currently the production of natural gasoline.

It is peculiarly fortunate that approximately the same ratio exists between the available amount of natural gasoline and the total production of motor-fuel, as exists between the proportion of natural gasoline that should be used in this motor-fuel if the most satisfactory quality is to be obtained. In other words, the production of natural gasoline is close to 10 per cent of the total gasoline production, while 10 per cent is a very satisfactory proportion in which to use natural gasoline with the average motor-fuel to give that motor-fuel the desired quality characteristics. When accurate figures are available, the percentage of production for 1922 undoubtedly will be found to exceed this, due, largely, to a great increase in its production in Texas. As the natural-gasoline possibilities of the existing oil-fields are now very largely developed, increased production will come almost entirely with an increased crude-oil production. A great increase in the percentage of natural gasoline available, compared to the total gasoline production, is therefore not to be expected.

The figure of 10 per cent given as the proper proportion in which to mix natural gasoline with motor-fuel is indicated by a large number of tests that have been made, but this percentage should be taken as a minimum rather than a maximum. As high as 20 per cent frequently is desirable. Thus it is seen that the problem becomes one of uniform distribution of the natural gasoline available, to the end that all motor-fuel consumed shall carry its most desirable proportion, and no motor-fuel be produced with an excessive proportion of it.

The use of natural gasoline in the past has been attended with varying success, depending altogether upon the experience and intelligence, or the lack of it, that has been displayed in combining it with other products to form the finished motor-fuel. Many arduous and expensive investigations have been conducted, in both the laboratory and the practical operation of engines, to determine the best possible proportions and combinations to secure an altogether desirable product. It is to the facts thus obtained that I wish to direct attention.

Blended Fuels

Prior to the acquisition of the present knowledge of this subject, natural gasoline was so commonly on the market in the form of blends improperly made as to place all natural gasoline in disrepute and to foster strong prejudices, the overcoming of which has required considerable time and a practical demonstration of the good results to be obtained by proper methods. The unsatisfactory types of blend referred to were unfitted for use as motor-fuel for one or more of the following reasons: first, some of them used kerosene as a blending base; second, too great a percentage of natural gasoline was blended with a heavy naphtha; third, natural gasoline of too high volatility was used.

In the first case, it was attempted to blend two entirely dissimilar products, the boiling-point range of one of which was entirely beyond that of the other. It also utilized kerosene, which the carbureter was not designed to vaporize and which, when finally introduced into the cylinder in a partially vaporized state, caused crankcase dilution and excessive knocking. The second and third practices resulted in the same trouble due to too great volatility; they caused an excessive evaporation-loss, gas binding in the gasoline feed-system, and an uneven operation and a loss of power when the engine was thoroughly heated-up.

The Association of Natural Gasoline Manufacturers is bending every effort to eliminate the types of blend that are objectionable, and to produce only blends that are satisfactory. It has issued and lately has revised standard specifications for blends of the several commercial grades. It has also formulated standard specifications for natural gasoline in its unblended state, so that the refiner can demand and receive the product suited to his needs.

Results of Tests

Evaporation tests conducted through every month of the year by a large refinery indicated that the evaporation loss on a blended gasoline containing 10 per cent of natural gasoline combined with 90 per cent of refinery gasoline slightly deficient in volatility, was no greater than the loss on a refinery gasoline of the same characteristics as the blended gasoline. With an increase in the natural-gasoline content to 15 per cent, the evaporation loss was very slightly greater than in the case of the refinery gasoline; but there was a compensating advantage in the volatility characteristics of the gasoline.

A long series of dynamometer tests conducted at full and one-half throttle over the entire speed-range from 400 to 1600 r.p.m. proved that the addition of 15 per cent of natural gasoline to a good commercial gasoline increased the brake horsepower developed and decreased the pounds of fuel consumed per horsepower-hour. The basic gasoline used was equal or better than the average gasoline sold along the Atlantic seaboard, having an end-point of 405 deg. fahr. The starting and accelerating characteristics were improved with each additional per cent of natural gasoline used and, although the improvements were very marked at 10 per cent, they did not reach the maximum increase in brake horsepower and fuel economy until there was a mixture with 15 per cent of natural gasoline. This means that the motorist who uses the fuel containing from 10 to 15 per cent of natural gasoline obtains more power at the same carbureter-setting or, by adjusting his carbureter, he can decrease the fuel-consumption. With either result he also enjoys much improved starting and accelerating effects.

A number of well known investigators have come to the conclusion that the temperature at which 85 per cent of the gasoline distills off in a standard distillation-test is of more importance than the end-point, and measures more nearly whether the gasoline will be vaporized completely in the engine after it is warmed-up. This point is fixed by the percentage of heavier constituents in the product and is controlled by the process used in the original separation from the crude, by either low or high-pressure distillation. In many instances the fractions cut that would be satisfactory, so far as either the 85 per cent point or the final end-point is concerned, do not make good motor-fuels, due to a deficiency in the light ends that are necessary for quick starting and snappy acceleration when more power is called for. Therefore, to obtain a good fuel, it is necessary either to sacrifice the yield materially or to add the proper volatile constituents.

Proper Blends of Fuel

The sacrifice of yield is no more desirable to the consumer than to the refiner, for such a policy generally carried out cannot but result in higher prices due to the natural law of supply and demand. However, by adding 10 per cent of natural gasoline, the initial boiling-point can be lowered from say 15 to 25 deg. fahr., and the percentage distilled at 212 deg. fahr. can be increased

by from 6 to 9 per cent. Thus, a gasoline that, unblended, would have an initial distillation temperature of 130 deg. fahr. and 18 per cent distilled off at 212 deg. fahr., would be improved with 10 per cent of natural gasoline to have an initial distillation-temperature of approximately 110 to 115 deg. fahr. and the percentage distilled at 212 deg. fahr. increased to 25 or 26 per cent. From all points of view, this would be a very much more desirable gasoline. If 15 per cent of natural gasoline is used, the initial boiling-point can be lowered 20 to 30 deg. fahr., and the percentage at 212 deg. fahr. can be increased by from 10 to 12 per cent. Thus, the same unblended gasoline mentioned just previously, combined with 15 per cent of raw, would produce a finished motor-fuel having approximately an initial boiling-point of 105 to 110 deg. fahr., and from 28 to 30 per cent distilled at 212 deg. fahr. Thus, the refiner can make his cuts to produce a product with the 85 per cent and the final points desired, and then increase the volatility of this product with the proper proportion of natural gasoline, thereby increasing his total yield of motor-fuel from the crude.

This improvement in quality by the addition of natural gasoline in high-grade motor-fuels is even more noticeable in the case of fuels of high end-point but still well within the range of commercial utilization. The results so far obtained by the joint tests being conducted at the City of Washington by the Bureau of Standards and the Society of Automotive Engineers indicate that a motor-fuel with an end-point of 465 deg. fahr. is as satisfactory, so far as mileage is concerned, as fuel with approximately a 405-deg. fahr. end-point. These are the results only of the summer series of tests, and the only appreciable disadvantage noted is the increase in the crankcase dilution. So far as we know, it has not been determined whether the dilution noted was sufficient to be detrimental. The fuel so used did not contain natural gasoline, at least not in a known or an appreciable percentage, and it has been requested that similar tests be conducted using fuel blended with a suitable proportion of natural gasoline.

Advantages of Natural-Gasoline Blends.

It undoubtedly is true that the principal cause of crankcase dilution is the excessive use of the choke required in starting on fuels not sufficiently volatile. In such cases a large quantity of gasoline, almost wholly in liquid form, must be drawn into the cold engine to obtain sufficient easily vaporizable gasoline to produce an explosive mixture. The large portion of the gasoline that is not vaporized drains past the piston-rings, destroying the piston seal, and enters the lubricating oil in the crankcase, greatly diminishing its viscosity and reducing its lubricating value. With the proper proportion of natural gasoline, sufficient volatile fractions are present to form an explosive mixture without drawing these large volumes of fuel through the engine. After the engine is warmed-up and under way, the additional volatility assists in more complete vaporization, and the complete combustion of the gasoline greatly reduces the possibility of dilution.

The action of an engine using a fuel of 437 or 450-deg. fahr. end-point is improved greatly when that fuel is blended with natural gasoline. The acceleration from low to high speed is rapid instead of sluggish. The fuel-consumption with the blended gasoline is lower in such accelerations tests, because it takes so much less time under open throttle to reach the desired speed.

Because of the economic factors involved, the trend seems to be toward fuels containing a greater percentage of the heavier ends and therefore of higher end-point. By combining with this fuel a proper percentage of natural gasoline to introduce the necessary readily volatile constituents, a motor-fuel of relatively higher end-point can be utilized with the same satisfaction as that secured from gasolines of much lower end-points. This will increase the available supply of gasoline from a given production of crude oil, and will benefit the consumer directly. When this stage is reached, generally, it is very doubtful whether the development of a kerosene carbureter will be required, as, by that time, the increased yield of gasoline will have reduced the kerosene yield to a point where it probably will meet only the regular demands for heat and illumination.

The conclusion that I wish to emphasize is that, through the uniform distribution of the available supplies of natural gasoline, so that substantially all motor-fuels will carry their due proportion of it, an increased quantity of motor-fuel of increased quality will result. This is a result devoutly to be sought by the petroleum industry, the automotive industry and the consuming public.

TERRAIN FOR GLIDER CONTESTS

A LONG ridge is preferred rather than a detached shaped hill. The slope must face the direction of the prevailing wind and should be reasonably uniform and of proper magnitude. The slope should be approximately 1 in 4 near the top of the hill, decreasing to 1 in 6 or 8 a short distance below the top. A constant degree of slope, however, would be satisfactory, even if it be nowhere in excess of 1 in 6. The hill should not be conical, but have a side broad and flat or somewhat concave in form as viewed from above. An ideal condition is a sloping valley facing the prevailing wind, wide and open at one end and contracting gradually between two ranges of hills until finally completely closed-off at the other end by the hill from which the flights would be started. Such a valley would, however, not only have to face the prevailing wind but no gliding could be done with any wind from any other direction. An open range of hills would have the very marked advantage of allowing a certain amount of deviation in the direction from which the wind blows.

A total drop of 1000 ft. from the hill to the plain below is highly desirable. A height of 100 ft. is the least that could be considered. The nearer the base of the hill approaches absolute sea-level height, the better. The surface must be smooth and as free as possible from trees, shrubbery, telephone wires or other obstructions.

Preferred locations are in parts of the country where the required velocity of wind during the hours that the contest is to take place occurs at not infrequent intervals; a mere daily average is not sufficient. The wind should be of more than 15-m.p.h. velocity, and preferably 20 or 25 m.p.h. continuously for hours at a time. The hill should be accessible by good roads and car-lines for the benefit of spectators and contestants.—Communicated by National Aeronautic Association.

Testing Leather Substitutes and Top Materials

By J. B. Davis[1]

Annual Meeting Paper *Illustrated with* Photographs and Charts

ALTHOUGH waterproof protective material has been in use for many centuries, particularly in the Far East, its manufacture in this Country was not begun until about 1850, and not until the arrival of the motor car did the demand for so-called leather-cloth cause its production to take a jump. This demand has increased until in 1922 the record-breaking quantity of 50,000,000 sq. yd. was consumed. The growing popularity of closed bodies has produced a corresponding call for leather-cloth and the importance of classifying and of embodying standard tests in the specifications for it is receiving close attention.

With the view to assisting in the establishment of uniform tests for the various qualities that are desirable in high-grade leather-cloth, the tests in use by one of the largest manufacturers are described, and suggested specifications for top material, upholstery and special body leather are given. Particular requirements will determine the desirability of muslin, drill, twill, sateen, moleskin or duck, and the suitability of each is judged by the weave, construction, thread-count, weight and the like. Among the qualities that can be determined by tests, directions for which are given, are resistance to wear; tensile strength; bonding-strength; resistance to stretch and puncture; thickness; toughness and adhesion of coating; resistance to water, shrinkage, fire and heat; cleansability and resistance to gasoline and the effect of aging.

FOR many thousands of years man has found various means for protecting himself against the elements. From the time of the earliest Egyptian and East Indian potentates with their gorgeous silk canopies to that of the present-day man who rides in his own motor-car, weather protective mediums have been in use. In the Orient the Chinese and the Japanese in particular provided themselves with waterproof cloths, silks and papers, which for many centuries have been manufactured largely by hand. They are now calling on the United States to supply them with a black leather-cloth for the collapsible tops used on the man-drawn two-wheel rickshaw, as well as for a small output of automobile bodies.

The first leather-cloth of any value was manufactured in England early in 1800 and was used principally for the hoods of perambulators, as it is used today. Leather-cloth was first manufactured in this Country about 1850. In the early stages of its development a few hundred yards a day was considered a big production, while today it is made at the rate of millions of yards a year for the automobile industry alone.

Several well-known automobile companies 20 years ago were building fine carriages, coaches and buggies, on which leather-cloth was used for tops, curtains, upholstery, storm-aprons and dashboards. The material was designed and constructed for special purposes at that time as it is today. With the first commercial production of motor cars early in 1900, the problem of weather protection came up for consideration and, naturally, the leather-cloth products that had proved so satisfactory for carriages were adapted to the early automobile; grandfather's buggy-top was becoming the one-man collapsible top. Some of you remember the carriages made with a dashboard and whip-socket of leather-cloth with patent-leather finish. As the automotive industry through the various stages of its development grew in both volume of production and quality refinements, so with it grew the volume of production and quality refinements of leather-cloth.

Present State of Development

The automobile industry in 1922 produced over 2,500,000 passenger and commercial cars including motor trucks and consumed approximately 50,000,000 yd. of leather-cloth of various qualities for approximately 20 separate and distinct uses in constructing and equipping motor-car bodies. A few of these uses are one-man collapsible tops, curtains, upholstery, linings, gimps, welting, trunk-covers and lining, mud-flaps, spring-covers, covers and curtains of truck cabs and the like.

In the last few years the patent-leather finish has been used largely in the construction of closed-car bodies. This retains all the good features of a metal-covered body with its full curved contour, and overcomes many of its disadvantages, not the least of which is the initial cost of working and finishing. You probably all have had patent-leather shoes forced upon you on some occasion and have noted their remarkable resistance to scratching. The non-scratchable quality of patent-leather finishes has many advantages over painted and varnished steel surfaces in body-construction.

Let us leave for a moment the possibilities of these new applications of leather-cloth to closed-car construction and consider its relative importance in the construction of bodies and tops for open models. Nothing can detract from the beautiful lustrous finish of car bodies more than a shabby, baggy, faded and dead-dull collapsible top. The top may have looked well when it was shipped; possibly it had a short life under weather conditions. Many of you probably have scratched your heads after a final look at your new model just out of the finishing department and wondered, "How will it look 6 months from now?" We all like to impress our friends and neighbors with our good judgment in buying a car. Our reputation as good purchasers depends, however, not only on the original lustrous appearance of our cars as we drive up in front of our homes on a fine April morning, but rather more on their ability to retain apparent newness through the biting sun and dust of July and August, the snow, sleet and cold of the winter months, the high winds and driving rains of March, and in certain localities, the effects of alkali sand and mud.

[1] Production manager, Standard Textile Products Co., New York City.

Many no doubt have watched a string of cars being driven up the main thoroughfare of a large city and noted the dead-dull appearance of many of the tops of the cars, obviously only a few months old. You may be assured by this sign that a disintegrating process has set in and that the material has begun to fail. When this condition is noticed by the owner and his friends, it is a subject for unfriendly comment that in no way satisfies his pride in his choice.

Standardization of Leather-Cloth

The enormous growth of the application of leather-cloth to motor-car bodies makes it prominent among materials, the requirements for which are being daily studied, specified and tested. The Society has made remarkable strides in standardizing automotive parts and material, having covered some 250 items since the inception of its Standards Committee in 1910. In carrying out this commendable program of standardizing, specifying and testing material you have established within your plants well-equipped chemical and physical laboratories for scientifically testing the materials that enter into motor-car construction. Would it not be logical to adopt uniform, scientific tests and to specify them for the leather-substitute products that add so much to the original appearance of the car and the continued satisfaction of the owner? There are very many makes of leather substitute on the market to choose from, none of which may be perfect. You can figure their comparative prices but not always their original qualities or their life, durability and service, nor can you match all the various quality characteristics one against the other, judging which products possess that proper balance of qualities that will best meet your requirements. A properly standardized test would place you in a position to distinguish the advantages and measure numerically the more important quality characteristics of any leather substitute.

Leather-cloths, of single or double texture, can be segregated, clearly defined and recognized under certain general classes, that depend upon the purposes for which each is to be used. The construction of the cloth used as a foundation, the dyeing and the coatings applied, all have a bearing on successful utilization. Selecting a suitable leather-cloth is almost as difficult as making it. As users you are interested first in the quality and secondly in the price; on account of the small yardage used on each car the price is of less importance. The two leading attributes are likely to be durability and appearance. In attaining these the responsibility of the maker is as great as that of the user. Each should have a scientific method of testing the products, for many instances have occurred in which on account of the lack of a proper test good products have failed of acceptance; and by the same token a few poor products have been adopted temporarily, usually to the ultimate loss of the user.

I shall show, with the aid of a few views and charts, how testing equipment can be utilized for measuring numerically the many qualities of leather-cloth and shall try to interpret the readings in terms of durability and permanence of appearance. The general appearance, with regard to luster, smoothness, softness, finish and color, can be judged and interpreted by comparing standard samples.

Method of Testing Quality

Many years ago it was the practice to set up in a field a group of discarded top-frames on which were stretched

Fig. 1—Former Method of Testing Life of Materials by Exposure to the Weather

the various materials for comparative test under actual weather conditions, as shown in Fig. 1. The tops were opened and closed from time to time. This necessitated a loss of time of 6 months to a year. This method does not serve in these days when decisions must be made and volume production had with the shortest possible delay to meet the rapidly changing condition of the market.

I shall present for your consideration the quality-test method for leather-cloth products that has been developed by our staff in cooperation with the United States Bureau of Standards. The serviceability of automotive leather-cloths depends not only on the raw material but on the process by which the goods are made. A chemical analysis will, as a rule, not be as indicative of quality as the physical tests that represent the stresses to which the goods are to be subjected in actual use. The nature and construction of the fabric, however, are of some importance. For example, a very heavy fabric would not be suitable for use in side-curtains that generally are folded or rolled up and tucked away under the seat of the automobile. On the other hand, upholstering material that is stretched and nailed and later subjected to severe usage must be made from a rigid fabric that cannot easily be pulled out of shape or torn. The particular requirements will determine the desirability of muslin, drill, twill, sateen, moleskin or duck, and the suitability of each is judged by the weave, construction, thread-count, weight and the like. These points may readily be ascertained by the ordinary methods of fabric analysis.

Weight is one of the most important physical characteristics and is easily determined by placing a definite length, as 12 yd., on a scale. The procedure may be carried out in the laboratory illustrated in Fig. 2. Samples are carefully chopped out with a 3 x 3-in. die. These are weighed in centigrams on a torsion-balance and the weight of the units of the desired area is established. For example, the weight in grams multiplied by the factor 5.08 will give the weight in ounces per square

Fig. 2—View of a Modern Laboratory Equipped To Test the Various Qualities of Automotive Material

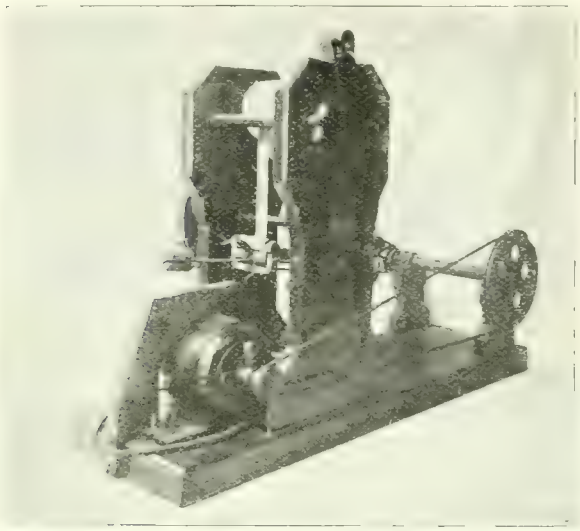

FIG. 3—ABRASION MACHINE DESIGNED TO REPRODUCE IN THE LABORATORY THE USAGE THAT AN UPHOLSTERING MATERIAL WILL RECEIVE IN SERVICE

yard. Ounces per square yard times the factor 1.04 will give the weight in pounds per piece 50 in. wide. The test is made under standard conditions of 65-per cent relative humidity and a temperature of 70 deg. fahr.

The uniformity of quality depends largely on the uniformity of weight. This does not necessarily mean that greater durability may be expected from very heavy materials. There appears to be a limit each way; extreme "body" is almost as bad as extreme "flimsiness." To secure a uniform product, it is desirable to establish a standard weight and provide for a reasonable degree of tolerance for each class of material. Conformity to the standard weight will result in a greater uniformity of strength and of wearing quality.

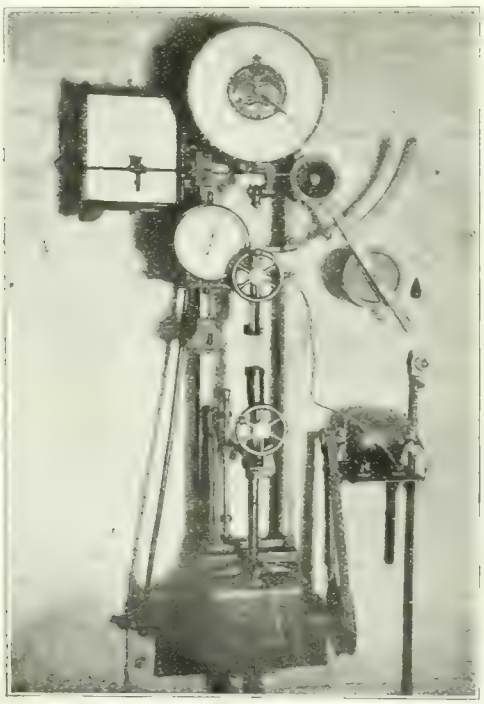

FIG. 4—THE SCOTT DYNAMOMETER EQUIPPED WITH AN ATTACHMENT FOR TESTING THE DEGREE OF ADHESION BETWEEN THE BASE AND THE COVERING

The severe usage that upholstering material must withstand in constantly rubbing against clothing very soon tells on cheap material. The coating wears away, peels off and shows the bare fabric, which has very little resistance to wear. In view of the fact that the material is placed under some degree of tension before it is nailed to the seat frame, the wearing qualities will be greatly reduced unless the coating is made of a very durable fabric. The abrasion machine shown in Fig. 3 was designed to reproduce as nearly as possible in the laboratory the exact type of punishment that the goods receive on a car. The method recommended is to fasten strips 30 in. long and 1 in. wide between the jaws of the abrasion machine at such a tension as to raise the weights just off the supports while the machine is operating. The most suitable wearing surface is a fresh piece of muslin that has a thread-count of about 60 x 60. The tension is adjusted during the operation to take up the stretch. The number of rubs is recorded upon a small counter that is attached to the machine. After 1000 rubs, and again after 2000 rubs, have been recorded by the counting attachment, the goods are examined, and at between 2500 and 3000 rubs the sample is removed. The test may be prolonged for special purposes. We have examined some samples on which the coating was very badly worn at 500 rubs and was so far removed that the fabric showed through at 1000 rubs. On the other hand, some materials are so durable that from 3000 to 4000 rubs are required to produce any noticeable effect. This test also indicates the resistance of top material to abrasive action. We consider this a very important test of leather-cloth on account of its direct indication of the hardness of the coating, which foretells the wearing quality.

It is important that the goods possess sufficient strength and rigidity to withstand the normal wear-and-tear of service. Limiting requirements should be adopted for each class of material. High tensile-strength is necessary for leather-cloth that requires great resistance to tearing or breaking under service strain. Good grades of properly constructed leather-cloth generally run higher than the corresponding grades of leather.

The "grab" method should be used to determine the tensile-strength. Strips are cut parallel to the warp and the filling threads should be 4 in. long and 1¼ in. wide. The jaws of the machine are set 1 in. apart with a 1-in. clamp. The speed of the lower jaw is regulated to 12 in. per min. and an average of at least three breaks is obtained. Table 1 shows the high and low points of a large number of samples examined in our laboratory, and indicates the variation that may be expected in the different commercial brands. If you desire a very strong material that cannot easily be ripped from the bows, you must subject it to a scientific test to determine its suitability.

TABLE 1—VARIATIONS IN THE TENSILE-STRENGTH OF AUTOMOTIVE MATERIAL

Kind of Material	Warp		Filling	
	Maximum	Minimum	Maximum	Minimum
Upholstery	215	100	160	90
Top	180	120	120	75
Curtain	145	70	95	50

To produce a piece of goods with a very even coating that will not appear thready when stretched, and at the same time to increase the strength and water-resistance

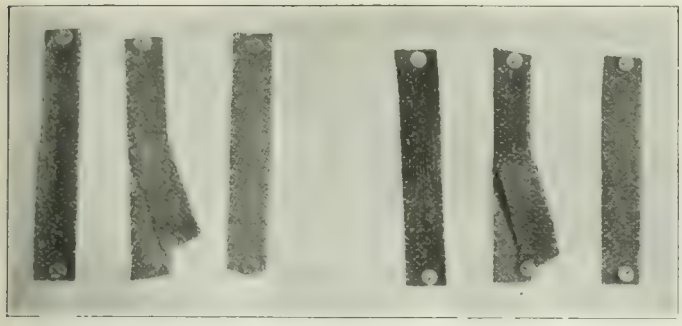

FIG. 5.—TYPICAL STRIPS THAT HAVE BEEN TESTED FOR ADHESION

and overcome the diagonal stretch due to the method of constructing sateen and twill-base fabrics, some manufacturers cement two fabrics together before laying on the coating. In such cases it is very important that the cement be very strong so that the plies will not separate when they are stretched over the bows of the automobile top. The separation of the plies results in general weakness and greatly reduces the resistance to water. The degree of adhesion between the two fabrics may be conveniently determined by an attachment to the Scott dynamometer illustrated in Fig. 4.

In testing the bonding-strength, strips 8 in. long and 1 in. wide are taken out parallel to the threads, in either the warp or the filling direction. The separation of the plies is started with a knife and they are stripped back about 2 in. One end is fixed in the upper jaw and the other in the lower jaw of the dynamometer. The mo-

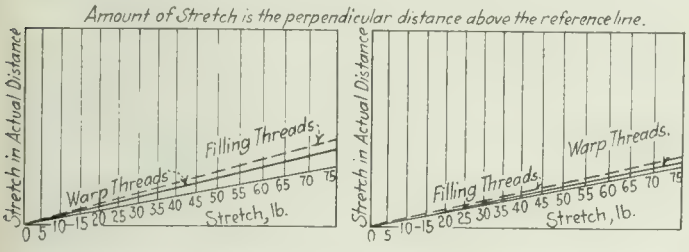
Amount of Stretch is the perpendicular distance above the reference line.
Stretch in Actual Distance
Warp Threads.
Filling Threads.
0 5 10-15 20 25 30 35 40 45 50 55 60 65 70 75
Stretch, lb.
Stretch in Actual Distance
Filling Threads.
Warp Threads.
0 5 10-15 20 25 30 35 40 45 50 55 60 65 70 75
Stretch, lb.

FIG. 6—STRETCH DIAGRAMS OBTAINED ON TWO SAMPLES OF TOP MATERIAL

tion of the lower jaw continues the separation at a uniform speed of 12 in. per min. The tension required is shown on the balance dial. This must be watched during the separation. The pointer will be approximately steady about an average point. Tearing the threads must be avoided by cutting the sample properly. For example, the pointer might vary from 2 lb. 6 oz. to 2 lb. 10 oz., in which case we should call the bonding-strength 2½ lb. per in. Fig. 5 indicates the nature of the strips used in the test and their appearance after they are separated.

You have all seen baggy tops that flap in the wind, sag and lose their trim appearance. The tendency toward this condition can be foretold by measuring the percentage of elongation under tension, by an autographic device attached to the fabric dynamometer. The jaws of the dynamometer are fixed 3 in. apart with the 1¼-in. clamps in place. The stretch is measured by actual distance above the base-line on the stretch-strain diagram and is recorded at 20, 40 and 60 lb. The samples are 6 in. long by 1 in. wide.

Fig. 6 shows the stretch diagram obtained on two samples of automotive top material. In one case the stretch is very high, amounting to about 9 per cent in the warp direction at a 60-lb. tension; in the other case it is less than one-half that amount. The test is, of course, very severe, and it is not to be supposed that an automobile top would ever be subjected to a force sufficient to stretch it 9 per cent. The figures obtained, however, are relative and it has been shown that the 9-per cent material is less satisfactory in actual service than the 4-per cent material.

The resistance to puncture is determined by a small steel foot that is pressed against the fabric, the force necessary to produce rupture being measured. The Webb testing-machine shown in Fig. 7 is fitted with a ⅛-in. foot, which is used over the No. 1 hole. The goods are placed under the foot and held by a clamp in both the warp and the filling directions while the pressure re-

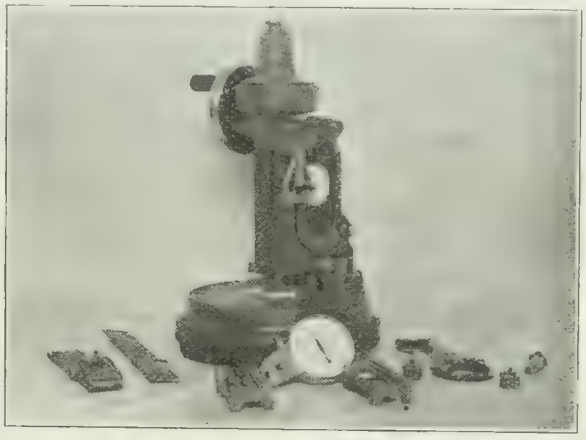

FIG. 7—THE TESTING-MACHINE USED TO DETERMINE THE RESISTANCE OF THE FABRIC TO PUNCTURE AND AT ITS SIDE THE GAGE FOR DETERMINING THE THICKNESS OF THE FABRIC

quired to puncture the goods is recorded. This instrument was designed originally to measure the breaking-strength of paper and strawboard. Various attachments that have been supplied with the device have made it suitable for measuring some of the qualities of leather-cloth. A flat 1-in. square foot that is furnished can be used to measure the resistance to cracking. It is not possible, however, to obtain so high pressures on the

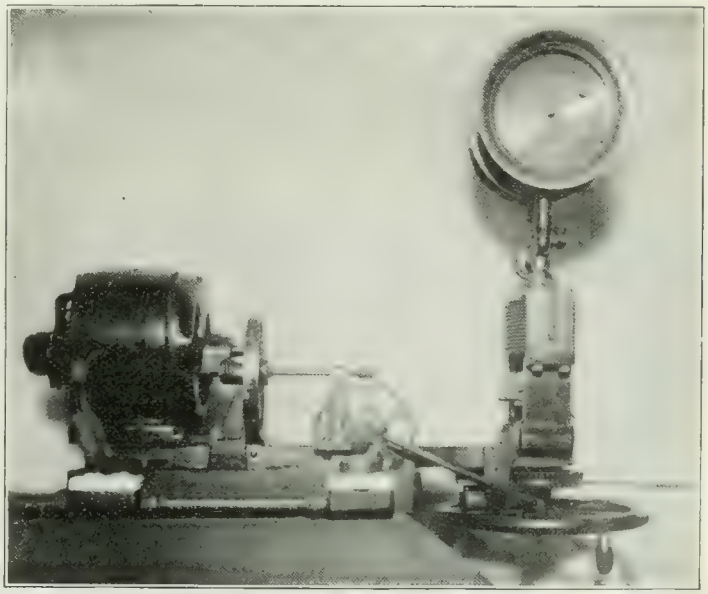

FIG. 8.—APPARATUS DEVISED TO MEASURE THE RELATIVE RESISTANCE OF THE FABRIC TO CRACKING

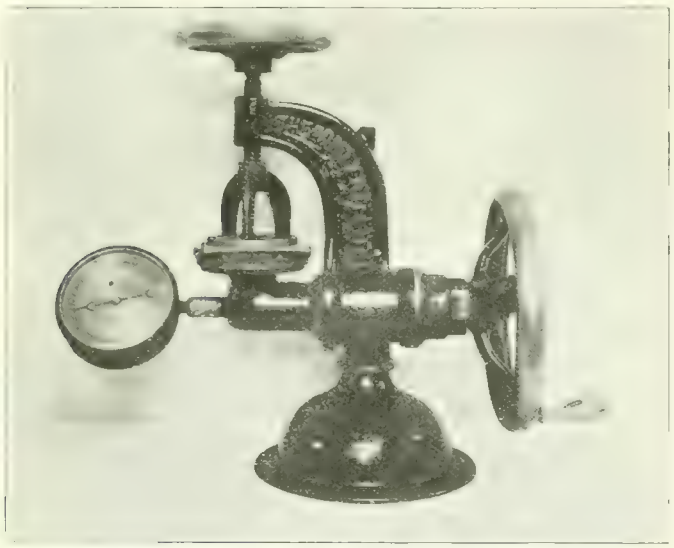

FIG. 9—TESTING-MACHINE TO DETERMINE THE RESISTANCE OF THE FABRIC TO WATER

water testing-machine shown in Fig. 8. In Fig. 7, alongside the Webb testing-machine, is shown an Ashcroft thickness-gage that is used for determining the thickness of leather-cloth.

The operations of folding and stitching will produce large cracks on an inferior material, whereas a high-grade product will withstand severe manipulation without injury. To determine the relative resistance to cracking the apparatus shown in Fig. 8 was devised. This instrument measures cracking pressures up to 200 lb. per sq. in. Many high-grade leather-cloths will withstand these easily. A few products are so brittle that they crack below a pressure obviously much too low to meet even the simplest manufacturing requirements. The test consists in taking strips 1 in. wide that are cut parallel to the warp and the filling of the base fabrics. These are folded into creases with the coatings up and placed beneath the foot of the testing machine. The pressure on the foot is gradually increased by rotating a handwheel until the coating cracks. The pressure is recorded by a diaphragm filled with water and connected with a pressure-gage.

The toughness of the coating sometimes is determined in a practical way by manipulating the goods between the fingers, in what is commonly called the "scrub test." There are a number of other so-called "hand-tests" that sometimes are used as a general guide. One of these consists of drawing some blunt instrument quickly across the coated surface; another is to fold the goods double and rapidly draw them apart. These tests are, of course, not more than general indications inasmuch as different persons do not perform them in the same manner.

FIG. 10—DETERMINING THE LIFE OF THE FABRIC BY PLACING IT ON AGING BLOCKS ON THE ROOF

In some cars that have been on the road for a little while you can see that the coating of the upholstery has peeled off in large pieces, the fabric beneath showing. In fact, the coating on some materials is anchored so poorly that it can easily be pulled off with a finger-nail. In a practical way, a general idea of the degree of adhesion can be obtained by the finger-nail test but it is far from exact and, of course, does not allow expression in numerical units. We have, therefore, designed an attachment to our crack testing machine to measure the adhesion properly and we recommend a method in which 1-in. strips of the goods to be tested are cut parallel to the warp and the filling threads. Near one end of each of these strips a flat S-bend is formed. A pressure of 1 lb. is then applied to the bend by the pressure jaws. The ends are fastened to a clip on the motor-driven revolving cylinder. The motion of the cylinder draws out the goods at a uniform speed. Various pressures are used until the minimum pressure at which the coating is stripped from the base is determined.

The importance of affording protection from rain is obvious in the case of topping and deck material. The relative resistance of various leather-cloths can be determined by placing a sample of the coated goods face-downward in the Mullen testing-machine illustrated in Fig. 9, after first removing the rubber diaphragm, filling the well with water and ascertaining the pressure necessary to force the water through.

Materials that have a very low degree of water-resistance can be tested by folding a piece of goods 20 in. square into a bag partly filled with heavy objects of irregular outline and immersed in water. The penetration after 24 hr. and again after 48 hr. is noted.

Several instances have occurred in which automobile tops have shrunk so badly that the bows have been pulled out-of-shape and loose from the frame. The shrinkage factor should, therefore, be predetermined. In making this test lines are ruled 10 in. apart on the sample which is then soaked in water at room temperature for 1 hr., drained and hung up vertically to dry. When it is completely dry, the distance between the lines is measured and the contraction is expressed as a percentage of the length.

It is, of course, not possible by any process to convert cotton or any organic substance into asbestos. It is desirable, however, that the coating material be not highly inflammable. The relative fire-resistance can be determined with strips that are cut 1 in. wide by 8 in. long and supported vertically so as to hang freely. One of the lower corners is ignited with a match and the time from the application of the match to the complete combustion of the strip is determined. This will include the time-interval for ignition as well as for combustion. The condition of the cinder and the rapidity of travel of the flame are noted.

A considerable variation among the numerous commercial brands of leather-cloth in their properties of heat-resistance exists. Some are affected very little by summer heat, whereas others "sweat" very badly when slightly warm. This "sweating" or "spewing" is very objectionable. To test fabrics for this characteristic the samples should be placed within a constant-temperature oven, adjusted to 150 deg. fahr., and allowed to remain for 2 hr., after which they are examined for tackiness and sweating. They are then allowed to come to room

temperature and are examined for any change in flexibility and permanent change in toughness.

To determine the ease with which it can be cleaned, the coating should be subjected to a practical test by washing small strips of it with soap and water and also with gasoline. There should be no appreciable loss of luster or injury to the coating. An alternative test in the case of laminated leather-cloth, or of the two-ply khaki top-material, is to soak it in gasoline for 24 hr.; after drying it no difference should be found from the condition of the original sample in either the bonding or the tensile-strength.

The final criterion of quality is how the goods stand up in service. It takes a long time for goods to deteriorate under the natural influence of sunlight, wind, snow and rain, when placed on aging blocks on the roof as shown in Fig. 10. To determine the relative merits of various fabrics quickly it is possible to expose the samples to the ultra-violet rays of a mercury-arc light, illustrated in Fig. 11, and obtain information in a few days that ordinarily would require several months, showing both the deterioration of the coating and the stability of the color of composite cloths.

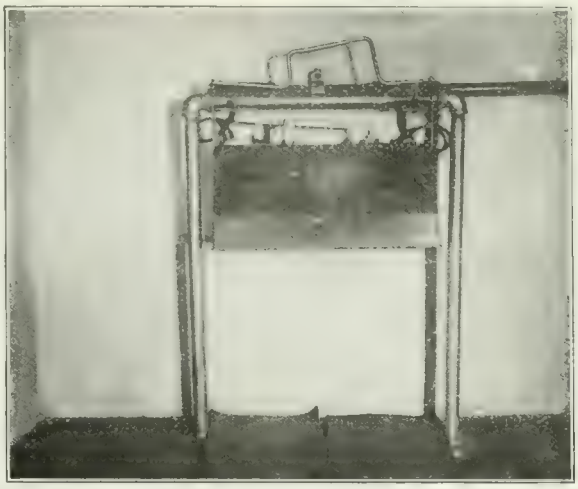

FIG. 11—MERCURY-ARC LIGHT USED TO DETERMINE THE LIFE OF THE FABRIC

The effect of exposure on the water-resistance is shown at the left of Fig. 12. These curves indicate how the water-resistance of a few of the samples decreased during the test. The curves of the center denote the gradual loss of flexibility and the stiffening-up with age, and those at the right show the gradual loss of toughness of a few of the samples. At the end of the year some of them were as cracky as a fountain-pen and would snap when lightly pinched between the fingers.

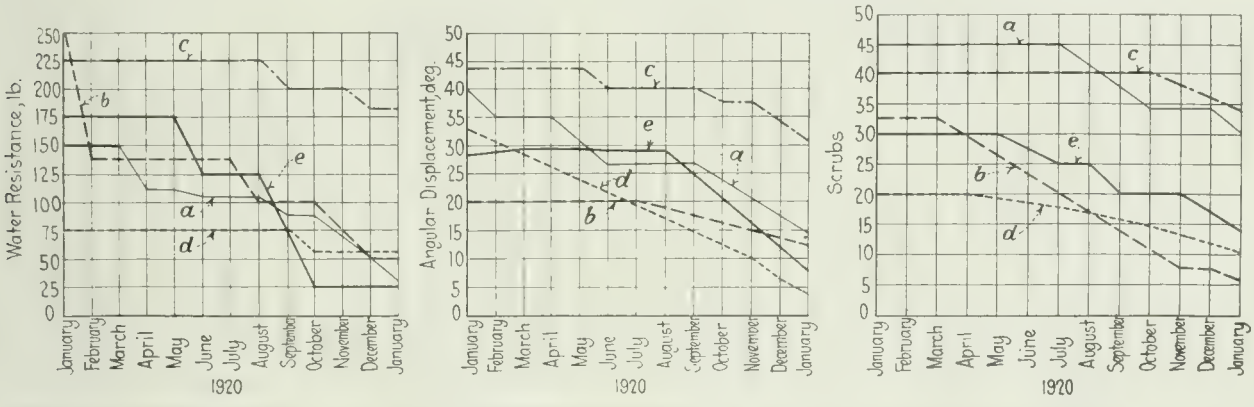

FIG. 12—CURVES SHOWING AT THE LEFT THE EFFECT OF EXPOSURE ON THE WATER-RESISTANCE, IN THE CENTER THE GRADUAL LOSS OF FLEXIBILITY WITH AGE AND AT THE RIGHT THE LOSS OF TOUGHNESS

MAINTENANCE OF UNIFORM QUALITY

The numerous properties have a wide variation among the different brands. To guard against fluctuations so that goods of uniformly high quality may be produced, it is necessary that the manufacturers take great precautions against defects in the finished material. In the case of the untreated raw material, the quality is assured by chemical analysis, and the uniformity of the treated products is maintained by careful control of the chemical and physical properties. The Doolittle viscosimeter, shown at the left of Fig. 13, has been modified to meet our particular requirements. The viscosity is determined by measuring the friction-resistance between the oil and a brass spindle.

TABLE 2—SKIN PROPERTIES OF OILS AND LACQUERS

Skin No.	Strength, Grams	Stretch, Per Cent
23	1,330	14
24	1,610	8
27	695	96
30	2,100	24
46	400	80
51	2,100	39
53	2,990	77
72	1,400	45
77	7,435	5
78	6,230	7
79	8,000	8
83	3,100	31
86	300	64
94	235	69
187	3,400	99

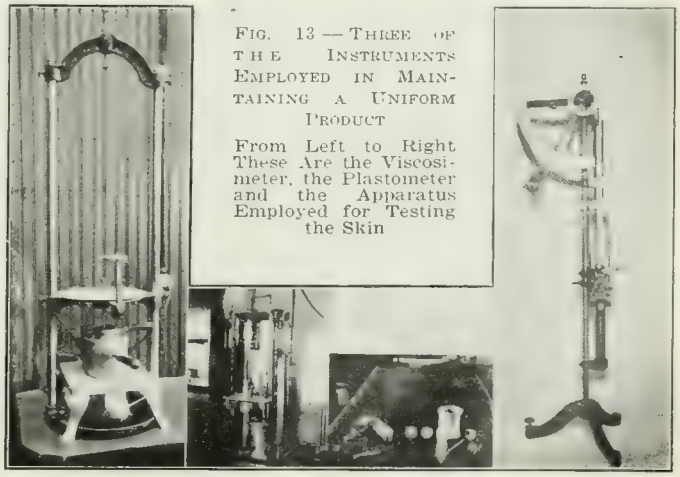

FIG. 13 — THREE OF THE INSTRUMENTS EMPLOYED IN MAINTAINING A UNIFORM PRODUCT

From Left to Right These Are the Viscosimeter, the Plastometer and the Apparatus Employed for Testing the Skin

The plastometer, illustrated in the middle portion of Fig. 13, is utilized to maintain the uniformity of some of the primary mixtures that are compounded to make the coating. The strength, elasticity and wearing qualities of leather-cloth are dependent to a considerable extent upon the character of the skin-forming material with which they have been coated. To obtain strength without sacrificing pliability, it is necessary to maintain the proper balance between the fabric and the coatings. The fabric must be chosen to furnish the necessary tensile-strength. Knowing the weave, construction, weight and the like, the coating materials can then be selected scientifically to yield the most serviceable products. The apparatus for testing the skin is shown at the right of Fig. 13.

Table 2 shows the variations in the skin properties of a few typical treated oils and emphasizes the necessity for choosing the proper materials carefully to obtain the desired qualities in the finished product. A microphotographic outfit, by which skin-forming properties are studied, is illustrated in Fig. 14. Fig. 15 is a microphotograph of oils showing two different stages of treatment. The skins formed from various coating vehicles do not in themselves possess the desired characteristics of strength and wearing quality. To increase the resistance to wear and at the same time meet the artistic requirements in color and finish, certain pigments must be incorporated into the mixture. These are purchased on specification and are carefully checked for uniformity.

Specifications for Leather-Cloth

To produce motor cars with all the features of design and construction carefully balanced and to give the purchaser the maximum return for his money, definite specifications for many of the mechanical parts have been adopted. The steel must conform to definite requirements; the instruments must meet certain tests; yet very few leather substitutes are purchased according to any agreed specification of quality.

Specifications covering three general applications of leather-cloth to special requirements are presented below:

PURCHASE SPECIFICATIONS FOR AUTOMOTIVE MATERIALS

Kind of Material	*Top*	*Upholstery*	*Special Coach*
Tensile-Strength of Warp, lb.	175 to 190	195 to 210	120 to 130
Tensile-Strength of Filler, lb.	95 to 105	150 to 160	115 to 125
Weight per Square Yard, oz.	20 to 21	23 to 24	22 to 23
Thickness, in.	0.0320 to 0.0330	0.0360 to 0.0330	0.0350 to 0.0360

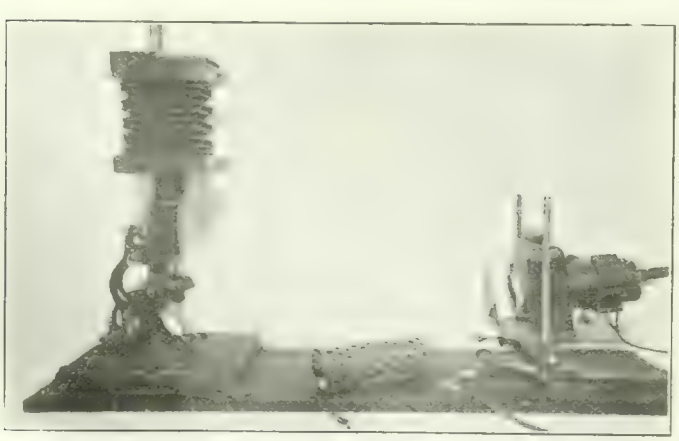

Fig. 14 — Microphotographic Outfit Employed To Study the Skin-Forming Properties

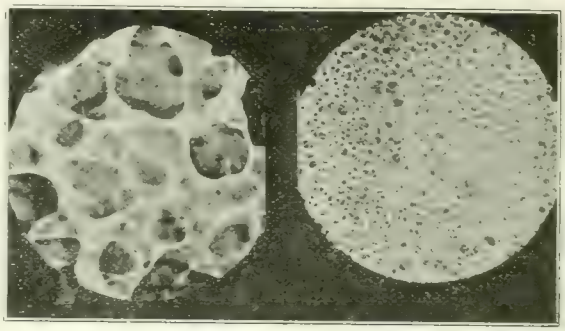

Fig. 15—Microphotographs of an Oil Showing the Results of Two Different Treatments

Toughness of Warp	30 to 40 (*a*)	40 to 50 (*a*)	200 (*b*)
Toughness of Filler	25 to 35 (*a*)	30 to 40 (*a*)	200 (*b*)
Resistance to Heat at 150 Deg. Fahr.	OK	OK	OK to Slightly Tacky
Resistance to Abrasion at 2,000 Rubs	OK to Slightly Dull	....	OK
Resistance to Abrasion at 3,000 Rubs	....	OK	....
Resistance to Abrasion at 4,000 Rubs	Slightly Dull to Dull	Slightly Dull	....
Resistance to Cold at 30 deg. Fahr.	No Cracking	No Cracking	....
Resistance to Fire, sec.	35 to 40	35 to 40	35 to 40
Cleansability with Soap	OK	OK	OK
Cleansability with Gasoline	OK	OK	OK to Slight Effect
Stretch of Warp at 20 Lb., per cent	0.75 to 1.00	1.50 to 2.00	2.00 to 2.50
Stretch of Filler at 20 Lb., per cent	1.50 to 1.75	4.00 to 4.50	4.50 to 5.00
Stretch of Warp at 40 Lb., per cent	1.00 to 1.50	2.00 to 2.50	3.00 to 4.00
Stretch of Filler at 40 Lb., per cent	1.75 to 2.00	5.50 to 6.00	6.00 to 6.50
Stretch of Warp at 60 Lb., per cent	2.00 to 2.25	4.00 to 4.50	9.00 to 11.00
Stretch of Filler at 60 Lb., per cent	2.00 to 2.50	8.50 to 9.00	8.00 to 9.00
Adhesion of Coating, lb.	4 to 5	5	4 to 5
Bonding Strength, lb.	2.50 to 3.00	2.50 to 3.00	2.50 to 3.00
Dryness	Good	Good	Good
Flexibility	OK	OK	OK
Resistance to Shrinkage of Warp, per cent	1.00 to 1.50	0.50 to 0.75	0.75 to 1.00
Resistance to Shrinkage of Filler, per cent	0.25 to 0.75	0.00 to 0.25	0.00 to 0.25
Smoothness	Good	Good	Good
Fabric Construction	Muslin and Drill	Muslin and Drill	Muslin and Drill
Thread Count, Muslin	62x50 to 66x58	66x60 to 64x58	52x50 to 48x46
Thread Count, Drill	62x34 to 66x40	109x46 to 107x44	72x60 to 68x56
Resistance to Puncture of Warp	325 to 350	330 to 340	200 to 210
Resistance to Puncture of Filler	285 to 315	380 to 390	250 to 260
Water Resistance for 48 Hr.	OK	OK	OK
Water-Pressure Resisted, lb.	80 to 120	200 to 250	240
Surfacing	Good	Good	Good
Luster	Standard	Standard	Standard

(*a*) Determined by scrubbing test.
(*b*) Determined by water test.

Maintenance Effects of Automotive Electrical-Equipment Standardization

By A. H. Packer[1]

Chicago Service Meeting Paper

THE author outlines past conditions that led to a diversity of design for similar parts, such as tires and rims, as being analagous to the causes of present variations in automatic electrical equipment intended for identical purposes, and gives specific instances in which such variation has resulted in excessive expense and delay.

Constructive suggestions are made for improvement in regard to reducing the number of types of equipment and standardization of the remaining types, more especially with regard to generators, as a means of making possible better service-station efficiency and a reduction of the investment now necessary because of the carrying of an excessive number of parts in stock. Standardization problems are stated and commented upon, and the advantages of a reasonable degree of standardization for electrical equipment are set forth.

TO get a vision of how present difficulties might have been avoided, let us start at the time when pneumatic tires were first being developed, and pretend that at that time there was the same amount of engineering initiative that we have in the industry today. Tire companies and motor-car companies were many, and none of them would consider having any part so common that it could be used on any other car. Accordingly, it happened that each motor-car company designed wheels having rims that required special tires. No two different makes of car could use the same size of tire, and the tire companies bowed to the wishes of their prospective customers and designed accordingly. Some cars required different sizes and types of tire on front and rear wheels; on others, designers thought that, due to the crown of the road, the tires on the right side should be larger, with the ones on the left side made oversize for foreign shipment.

After these companies had distributed several million cars to purchasers uninformed as to the real meaning of variations of this kind, tourists often had the experience of being stranded while waiting for a tire from the factory because, unless the local dealer handled that particular make of tire, there was no chance of getting some other make to fit. Each motor-car company continued to justify itself regarding this policy by the fact that customers had to come to it for tires, forgetting that it was automatically closing its doors to the possibility of a great amount of additional replacement business. Some of the smaller tire companies went out of business, but the larger ones could not profit by this because they had nothing to sell the former customers of the other organizations. Nor was this the only way in which the whole industry was limiting itself. Prospective buyers hesitated to buy cars because blowouts of tires might necessitate expensive hotel bills while waiting for a new tire or the abandonment of the car and returning home on a railroad train. Such negative advertising passed from one car-owner to another and increased sales resistance so that competitors were forced to get together to see what was wrong and try to correct it; and this is the point at which we find ourselves today.

The foregoing outline is a close parallel to the condition that exists today in regard to automotive electrical-equipment. Not only do we have a multitude of starting motors, generators and ignition devices, that fit on one car and one car only, but we have wiring schemes that have very different arrangement on the car, although they are the same in principle. This is a source of annoyance not only to the owner of the car but to the average man in the small electrical station as well. A man in a small town does not have a sufficient quantity of work to make him familiar with the wiring on all of the various makes of car. However, if the circuits were analyzed, we would find them essentially the same; accordingly, it would seem possible to get some systematic way of wiring all cars.

For example, the tail-lamp wire might be designed to run back along the left side-rail of the frame or body; a standardized location of the fuses would help; a standardized color scheme for the wires, long discussed, would facilitate trouble-shooting; and a definite location for the terminals on the back of the lighting-switch would make it easier for all concerned. This would mean, for example, that the tail-lamp terminal would always be at the bottom, the head-lamp terminal always at the top and the battery terminal always in the center. Then an electrician could locate wiring or circuit trouble on any car more quickly and easily, and the customer would have just that much more satisfaction from his car. Regarding standardized color-schemes, a certain magneto made some years ago had a cable from the magneto to the coil, the three wires being colored red, green and yellow and the terminals on the coil marked *R*, *G* and *Y*; the average man thus was able to get the wires on the right terminals.

An endeavor has been made to improve the available facilities for training men for maintenance work because the present schools are inadequate. This takes time, but we can improve conditions in automotive maintenance by making the various jobs easier as well as by making the workman more skillful. At present it is a gamble as to what will happen to a car if some small-town battery or electrical man is asked to locate trouble in the wiring. Occasionally, a good man at this work is found, but this is not the rule. Few so-called electricians know the fundamentals of the wiring of cars sufficiently well to shoot trouble on an unknown model, and the variation in the wiring plans is so great that it is impossible for any man to memorize them. Nor do wiring manuals help out in every case. One reason is the cost, which prevents all but the most farsighted from using this kind of assistance. Others do not use diagrams because they do not know how to read a blue-print; the lines on the paper mean nothing to them so far as tracing the wires is concerned. This class of man is working on the cars we build and, whether we acknowledge it

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or not, he is our agent in the eyes of the car-owner. Whatever trouble he causes and whatever mistakes he makes in working on our customers' cars, he will never ascribe them to his own inability but will blame the manufacturer for putting out a pile of junk and making a mess of the wiring. Such things do not promote sales; they kill them. That is why, in self-defense, we should standardize wiring so that, if a man had ever traced the tail-lamp circuit on any car, he could go to any other car and trace the same circuit with equal facility. Variation in wiring schemes makes maintenance difficult but not impossible. On the other hand, the variation that exists in the construction of the electrical equipment on the car cannot be overcome by any amount of training that the electrical man might have. The expense that this entails is borne by the automotive industry.

To illustrate what special design really means, some years ago, when working for an electrical company, my time from 3:00 to 10:00 p.m. was taken up in reaching a small town where a job awaited me. The local power-house was operated overtime for 1½ hr. to provide light in the garage, through influence, only to find that the car in question was equipped with an ignition generator different from that used on any other car, that nothing in an ordinary garage would replace it and that no near-by town garage or dealer could help out. Even when it was customary to render service of this kind, it showed a condition that is far from right. Someone must pay for expensive maintenance of this nature. If the factory stands up under such strain, it is due to the fact that the expense has already been passed along to the customer by increasing the first cost of the equipment.

Even today conditions in this respect are not appreciably improved. I visited a small battery-station recently, in a town about 30 miles from Chicago. While I was there a man came in to see about a generator he had left for repair. Examination had shown that it needed an armature, bearings and brushes. The shop did not have these, nor was there any place nearer than Chicago where they could be had. The generator, as usual, was used on that particular car only, and the parts could not be obtained within 4 or 5 days. In the case of this particular car, it was possible to run without the generator being in place; but, if it had been a car on which either the oil-pump or the water-pump was driven through the generator, or ignition apparatus was mounted on the generator, the holdup would have been complete. The average service-station in a small town has small chance of having in stock whatever part a car-owner may need. In checking-up a wiring manual recently, I found listed therein 791 diagrams of different cars, 14 different generator makers in active production and 171 different types of generator made by these companies.

Proposed Service Improvement

The Automotive Electrical Association proposes to establish stations throughout the Country which will handle service on all makes of electrical equipment. This is a step in the right direction, but how can it possibly succeed in doing this where the community is so small that the sales will not pay the interest on the stock investment? In a small electrical service-station not far from Chicago, two partners are working their heads off and claim to have over $8,000 worth of stock. They told me about what sums they were able to draw out of the business each week. I figured that if they subtracted the interest on their investment they would find they were making less in a week than they could easily get if working for someone else. These men are subsidizing the industry to the extent of their investment; they do not realize it. If this same station were handled by a business man capable of figuring his interest, depreciation of equipment and kindred factors, he would find it necessary in a small community of this kind to increase prices so that these overhead items would be taken care of. The burden would then fall on the car-owner, just as it does now, but it would be a cash burden rather than one of inconvenience.

Another example of extreme inconvenience caused by the lack of uniformity in electrical equipment is shown by the experience of a man who was driving from Milwaukee to Chicago. He was passing through one of the small towns near Chicago, when his car suddenly stopped. He called on an electrical service-station and it was found that the distributor-arm in the battery-ignition system had been punctured. The electrical station acted as official service agent for one or more makes of equipment but not for the one in question, and the man had to abandon his car. Now there is no patent on the shape of the upper part of a distributor-shaft, and there is no reason why there could not be some uniformity as to the radius through which a distributor-arm swings. Except that distributor-arms of various makes do not fit in place of each other, they are very similar, and there seems to be no reason why they could not eventually be made interchangeable. Such a suggestion will, no doubt, be objected to by a number of engineers, but advancement in any line is attained only by subordinating personal opinions to the good of the many. If the present S.A.E. Standards were more generally used, this man would not have been forced to leave his car. In an emergency, a busy man probably would prefer to buy a whole distributor of another make, rather than lose the use of his car for several days. But even with the best of standards, well worked-out by wise committees, there will be no appreciable benefit to cars already in the user's hands. However, the industry is progressing. We must work for the period 10 years hence, or our anticipated progress will fail to materialize.

Standardization Problems

How shall we begin to standardize? A proposed basis, taking into consideration the electrical characteristics of the machine, has been outlined, but how will this help the maintenance shop unless the mechanical dimensions also are determined? And, if both the electrical characteristics and the mechanical dimensions are predetermined, are not some of our engineers right when they say that standardization would remove all chances for initiative and for development in the art? We would be on a war basis, building for production only according to planning already done.

The car-owner and even the service-station proprietor do not care much whether a generator charges a battery at 12 or at 14 amp. Furthermore, if it does charge at 12 amp., that may be too much for the way some cars are run and 14 amp. may not be enough for other classes of usage. Of course, if a generator charges only at 5 amp. and the battery has to be charged every 2 weeks, someone will let us know about it. On the other hand, if the generator is one of the ultra-enthusiastic kind and has a propensity for throwing out solder and loosening its armature leads, there will also be a comeback; but, in between these extremes, the exact charging-rate is not so vital as engineers would lead us to believe.

On the other hand, suppose we should proceed with

the standardization after the following fashion: Make a survey of generators now in production that have an output of say 12 amp. at 8 volts at 1500 r.p.m. without destructive heating; take a number of such generators and consider their length and diameter; consider the length and diameter of the armature core, the size of the commutator and the brushes, the size and location of bearings, and lay-out a standard generator on this basis. We now have the mechanical dimensions pretty well-defined, but they have not limited initiative. Perhaps some particular electrical-equipment company that has extensive research facilities will develop a grade of iron in which the heat losses will be less than those in commercial laminated steel. By this means it may be able to put out one of these standard machines that will either have a greater output at the same temperature, or have a lower temperature for a specified output. In either case the company purchasing such a machine would get more for the money, or that machine might be sold for more than the average standardized machine. Perhaps some other similar company would develop a new type of insulation that would withstand excessive heat, due to overloading or overspeeding; it might thereby have a product superior to that of some other companies.

Standardization of complete machines would be a step in the right direction. It would make possible the use of a rental machine while the machine from the car was being repaired. However, by visiting a number of service-stations, it will be found that, as a rule, no attempt is made to keep complete machines in stock. The present reason is their high cost, combined with the fact that it is impossible to have enough different kinds of machine to fit all cars. Then again, as a rule, the customer does not wish to pay enough to have a complete machine put on, except in very unusual circumstances.

About the most common part carried in stock is the armature. While the cost of this is, of course, not so much as that of a whole machine, it is enough to prevent all but the very largest establishments from having a sufficient variety of armatures to handle the general run of cars. It seems that standardization of armature sizes would be of the greatest benefit to the electrical-maintenance division of the industry. It would require fixing bearing dimensions and their relation to the armature core and commutator. The size of the core, both the diameter and the length, would have to be set, and the commutator size would have to be fixed. Here, of course, we run into questions of design. In a machine of fixed external dimensions, one engineer might figure some advantage in a fairly large armature, with less space for the fields, while another engineer might favor a smaller armature with greater field-space. It appears, however, that an analysis of a number of machines would determine average dimensions that could be adhered to. It may be said that, even if an A-type machine is standardized so that the armatures are all alike in regard to external dimensions, they may not be interchangeable electrically. That may be true at the start, since we have four-pole machines and two-pole machines, but it should be possible to settle on one of the types as standard. In fact, most of the generators now in use are four-pole machines. In regard to the manner in which armatures are wound, it makes little difference whether progressive or retrogressive winding is used, if all armatures use the same method of winding. Even if engineers should insist on their right to individuality in this particular respect, it would be easy for the service-man to reverse the fields and make the armature suffice.

The question of brush position also is one that would have to be settled before an armature would be interchangeable with that of some other type of machine. Here again the fundamental nature of the winding is determined by electrical laws that no engineer can alter. The brush must be placed on the commutator so that it rests on commutator bars connected to coils that are generating little or no voltage at that instant. From bars under a brush, the winding invariably goes to a point between the poles. If the brush is located under the pole, it must go off to one side a little more than half the pole width. In the other direction, the winding also goes off at an angle for about half the pole width. The other possible brush position is between the poles. In this case one armature wire must go straight up to get into the neutral zone, while the other must go over at an extreme angle the distance of the whole pole-width and a little more, to get into the next neutral zone between the poles. The point is that the electrical operation in one case is the same as in the other, and special armatures would have to be made for each type. There is, however, no reason why all such machines could not have the center of the pole as the standard main brush position. Regarding what latitude this would give the designer and wherein he would have a chance to develop his product, variation in the number of commutator bars would still be permissible if the diameter were kept the same. Variation in the slots, in the quality of the iron, and in the relation of field ampere-turns to armature ampere-turns would still be possible, so that we would continue to have machines differing somewhat in electrical performance. Perhaps some, more expertly designed, would have better commutation and therefore have greater brush-life.

It may be said that the interchangeable feature for an armature would have little value if the electrical characteristics were not identical but, according to my experience, this is not the case. To show how it is possible to take liberties with the design of a machine and still make it work, while in charge of a certain service-station I received a telegraphic order for a generator to be sent to a tourist in Canada, whose machine had quit. The machine on the car in question was a 12-volt generator, and all we had in stock was a 6-volt machine of the same size. This was modified, so far as protecting its field was concerned, by installing a quickly made resistance unit, equal in value to the shunt-field resistance. The regular 6-volt armature was used for this 12-volt machine, and it worked all right. This generator came back, in about 6 months, not because the idea was not all right for an emergency, but because the resistance unit had been mounted inside, where it did not cool sufficiently, and it had eventually burned-out. This illustration is an extreme case, for the run of 6-volt armatures do not differ nearly so much as was true in this instance.

Any car-owner would rather have an armature put in that charged at 2 amp. less, than wait 2 days for some other kind. Again we have found that, even if one armature has seven turns per coil and another nine turns, they can be interchanged without much trouble. Third-brush adjustment is capable of giving approximately the same results in either machine. If the armature with few turns were put into the other machine, the brush could be advanced slightly; if the opposite were true, the brush could be moved back somewhat. It is interesting to note that the 15 makes of car that are in heaviest production all use generators having the third-brush method of regulation.

About 150 kinds of generator armature must be kept

in stock at present. Many of these armatures are so nearly alike that careful examination is needed to determine their differences. Two of these made by one company are identical except that the diameters of the shaft-end on which the sprocket goes are different. It is probable that when the sales department solicited orders for a certain machine the purchasing agent's reply was to the effect that he had several thousand sprockets in stock that could not be used on the department's regular machine, but that the same generator made with the shaft size to suit those sprockets would secure the order. Thus the special armature came to be made, to be a burden to service-stations ever-after.

Assuming that we could equip cars at present with standardized machines only, and that within 10 years the present cars would have had their present generators replaced with standardized generators, we would have reduced the number of types of armature in stock from 150 to 5. Let us say that there are 1500 electrical service-stations that are carrying at least a full set of armatures and that the average dealer's price on these is $10 each. On this basis we have a minimum investment of $2,250,000. Furthermore, this is only on a basis sufficient to take care of one customer on any particular armature. Now if we assume that the 10-year period of readjustment has passed, we find the investment reduced to $75,000, a difference of $2,175,000. Not only is this enormous reduction of investment possible throughout the Country, but any small battery or electrical station having $50 to invest can acquire a stock of five armatures that will take care of any job that may come his way. At present such a thing is entirely out of the question. This $2,175,000 represents some $130,500 saved in interest. If we take Ray Sherman's figures of 10-per cent average total net-profit as being just, we find that a business of $1,305,000 would have to be done to accomplish as much. Let us remember that these figures are based on generator armatures only, no motor-generators or starters having been considered. If these also could be standardized, the saving could be more than doubled. The calculation was made on a basis of only one armature of each kind in stock, whereas most stations carry a number of the more popular types.

It is impossible to measure in dollars the value of such a condition to the automotive industry. For example, in case of a fire or a strike that might tie-up a large electrical plant, other equipment would be available and might even be secured by this plant to satisfy its customers and keep its business. Again, having parts available in all regions of the Country instead of in the larger centers only should give such satisfaction to car users as to react in greatly increased sales and prosperity for the whole industry. There is no great agitation in the spark-plug field in favor of 150 different types of thread instead of some three or four, or any agitation in favor of 150 different types of plug and socket for lamp fittings. We have two types now, and that is one too many. Standardization of those parts has not cut into anyone's business, but has made possible increased production, sales and profits.

THE EDUCATION OF ENGINEERS

SCIENTIFIC knowledge is not the only ingredient necessary for the making of an efficient engineer; and although knowledge of ascertained fact is required, and in the fullest possible measure, in order that it may be employed as a basis for projected designs, the knowledge likely to be most valuable as giving clear vision in these respects is that full comprehension of plain physical reality which enables a man to form a reliable prediction as to the probable consequences of a proposed action, and to trace backward accurately from an observed result to the causes of which it is the effect. Engineering deals always and solely with actual physical realities; and the mathematics of engineering must be taught and studied throughout in terms of physical reality if the school work is to form a suitable foundation upon which the real education of an engineer may be built.

The activities of the human mind may be classified under three broad headings: (*a*) imitative, (*b*) interpretative and (*c*) originative. Such a classification is already recognized, tacitly, at least, but the fatal error is made of attempting to apply the classification to individual minds instead of to the activities of each and every mind. In such imitative work as the manufacture of ordinary sewing-needles there is wide scope for the exercise of both the originative and interpretative faculties. In the essentially interpretative work of the ordinary commercial drawing-office and machine-shop there is of necessity much that is almost purely imitative, while there is also need for originative ability without in any way encroaching upon the preserves of design. And in the originative work of design, administration and organization there is inevitably much that is imitative, and also very much that is truly interpretative.

It would be difficult, if not impossible, to define the precise boundaries between any two of these fields; and it would appear unlikely that any useful purpose would be served by such definition. All three should be cultivated and developed, with equal assiduity and care, in each and every mind, for all three are of equal importance, instead of endeavoring to produce here and there a few minds that shall give out original ideas constantly and exclusively; and a few others that shall do nothing but interpret the ideas originated by their superiors; while the main bulk are left to wallow in mere imitation. The latter course has been followed for a long time and is now obviously found wanting, a result that is not surprising, seeing that the method is altogether unnatural.

It is, of course, true that the higher ranks of the profession are concerned with originative work to a greater extent than are the lower ranks; and that, consequently, personal progress in it must be upward from work that is mainly imitative through that which is mainly interpretative. But no argument is needed to show that every individual member of it, as well as the profession as a whole, would benefit enormously were the fact recognized and made clear to all that, throughout life, the three faculties are all of equal importance in each mind, and should be cultivated and developed with equal care; that work which is apparently of the most imitative character demands the exercise of the interpretative and originative faculties if it is to be really well done, and that it is impossible for a man to originate any truly good project unless his imitative and interpretative faculties be thoroughly keen and well developed.—E. G. Beck in *Engineering* (London).

Further Data on the Effective Volatility of Motor-Fuels

By Robert E. Wilson[1] and Daniel P. Barnard, 4th[2]

Annual Meeting Paper *Illustrated with* Drawings and Charts

SINCE the authors presented a paper on the subject that included the test results of only three fuels, the number of fuels investigated has been increased to 14 and several improvements have been made in the method relating to the manner of the preparation of the equilibrium solution and in the apparatus used for the measurement of vapor-pressures.

In addition to describing these improvements, the present paper includes data on the fuels; a series of empirical curves from which it is possible to determine, aided by the data from the distillation curve, the dew-points of non-aromatic hydrocarbon fuel; a table showing a comparison of the more important properties of the fuels; and definite evidence that the 85-per cent point is the best single measure of the effective volatility of a motor-fuel, from a standpoint of distribution and crankcase dilution.

IN a previous paper entitled Condensation Temperature of Gasoline and Kerosene-Air Mixtures[3], the authors presented a new method for the measurement of the dew-points, or initial-condensation temperatures, of motor-fuels when mixed with air in various proportions. At that time the experimental work had been confined to three fuels, Socony kerosene, Socony gasoline, and an artificially prepared high-end-point gasoline. Since then, however, the number of fuels investigated has been increased to 14, much of this work being done in connection with the cooperative fuel research program conducted jointly at the Bureau of Standards by the American Petroleum Institute and the Society of Automotive Engineers. The larger number of fuels now includes specimens ranging in volatility from the lightest fighting-grade aviation gasoline to a rather high-boiling commercial kerosene.

Since the presentation of the first paper, several minor improvements have been made in the method, chiefly in the apparatus for the preparation of the equilibrium solution and that for the measurement of vapor-pressures. The more extensive data have also made possible the development of a series of empirical curves from which it is possible to determine with a fair degree of accuracy the condensation temperatures of an ordinary motor-fuel from the data given by the standard distillation-test.

This paper contains (*a*) certain modifications and improvements in the method developed previously by the authors for preparing equilibrium solutions and the measurement of the vapor-pressures of motor-fuels; (*b*) data on the effective volatility of 14 different fuels, covering a very wide range of volatility; (*c*) a series of empirical curves from which it is possible to determine the dew-points of a non-aromatic hydrocarbon fuel, aided by the data from the distillation curve, with a degree of accuracy sufficient for all ordinary purposes; (*d*) a table showing a comparison of the more important properties of the fuels investigated; and (*e*) definite evidence that the 85-per cent point is the best single measure of the effective volatility of a motor-fuel, from a standpoint of distribution and crankcase dilution.

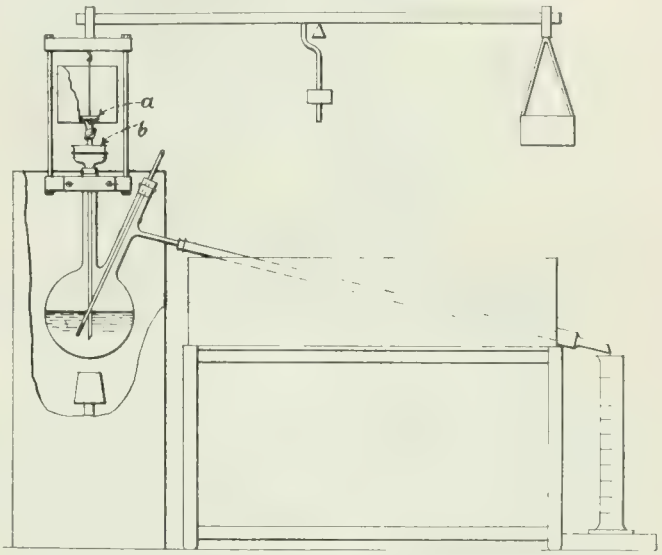

Fig. 1 —Automatic Form of Apparatus That Has Been Developed for the Preparation of Equilibrium Solutions

Equilibrium-Solution Preparation

The experimental work involved in the determination of condensation temperatures divides itself into three steps: (*a*) the preparation of a mixture known as the equilibrium solution and which has the same composition as the first drop of liquid that would condense from the dry vapor on gradual cooling; (*b*) the measurement of the vapor-pressures of this solution and of the original fuel; and (*c*) the standard Engler distillation-test on the fuel. The last operation furnishes the data from which the *approximate* average molecular weight is determined.

The first step involves the distillation of the fuel under such conditions that fresh fuel is supplied to the flask at the same rate at which the vapor is being condensed, the distillation being continued until the temperature becomes constant and the incoming and outgoing liquids have the same composition. To obtain equilibrium requires from 1½ to 3½ hr. It therefore becomes desirable to construct an automatic device that will maintain a constant level in the distillation flask, and eliminate the necessity of the continual attention of an operator for this considerable period of time. Such an apparatus, shown in Fig. 1, has been constructed in the laboratory of the Massachusetts Institute of Technology. The apparatus consists of a distillation flask having two

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[3] See The Journal, November, 1921, p. 313.

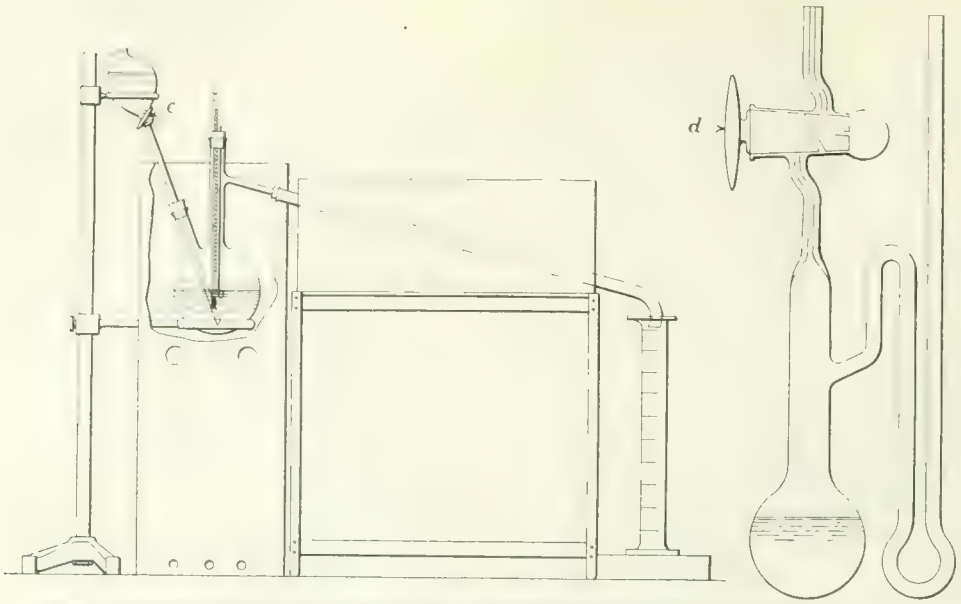

FIG. 2—ANOTHER FORM OF APPARATUS FOR PREPARING EQUILIBRIUM SOLUTIONS AT THE LEFT AND AT THE RIGHT THE VAPOR-PRESSURE BULB WITH A SPECIAL FORM OF CAPILLARY VACUUM STOPCOCK

necks supported at the end of a balance beam. As the flask rises, due to the boiling away of some of the liquid, the valve *a* is opened and admits fresh fuel. The escape of vapors through the supply tube is prevented by the use of a flexible paper diaphragm shown at *b*. In practice, the operation of this apparatus was very steady, showing no tendency to admit fuel in "slugs." The last portion of the distillate collected after the equilibrium temperature had been reached gave almost identically the same distillation-curve as the original fuel, provided care was taken to condense the vapors completely. The use of the two-necked flask was resorted to to avoid the fractionating effect of the incoming cold fuel on the hot vapors, and also to simplify the construction of the apparatus.

A second apparatus also has been devised, as shown at the left in Fig. 2. In this scheme also the two-necked flask is again used, coupled with the condenser used in the standard distillation-test. The rate of feed of fresh fuel is controlled by the manually operated stopcock, *c*. It has been found that this arrangement requires the attention of the operator but once in every 10 to 15 min. The use of the oil heating-bath has been discontinued in both cases, as a properly shielded direct gas-flame gives much steadier operation and less bumping.

Most of the equilibrium solutions used in the following measurements were prepared in this latter type of apparatus and, in each case, the last sample of distillate was found to correspond very accurately with the original fuel. It also has been found unnecessary to distill off more than twice the volume of the liquid in the flask *after a constant temperature has been reached.* Indeed, samples of the distillate collected but a few minutes after the equilibrium temperature had been attained agreed very closely in composition with that of the original fuel.

VAPOR-PRESSURE MEASUREMENT

Only one important modification has been made in the apparatus employed in the measurement of vapor-pressures. This consists in the employment of a specially constructed capillary vacuum stopcock, *d*, at the top of the vapor-pressure bulb; the bulb, as used at present, being shown at the right in Fig. 2. To make sure that this apparatus was giving reliable results, vapor-pressure determinations of several pure compounds were made; namely, benzol, water and absolute ethyl alcohol. These determinations were found to agree within 1.0 deg. cent. (1.8 deg. fahr.) with the data given in Landolt-Börnstein[4] and in Marks' and Davis' steam tables[5]. An additional check on the accuracy of the vapor-pressure measurements is afforded by the fact that the curves pass through the point of equilibrium temperature at a pres-

[4] See Physikalische-Chemische, Tabellen, 1920 edition.
[5] See Properties of Saturated and Superheated Steam, by L. S. Marks and H. M. Davis, 1909.

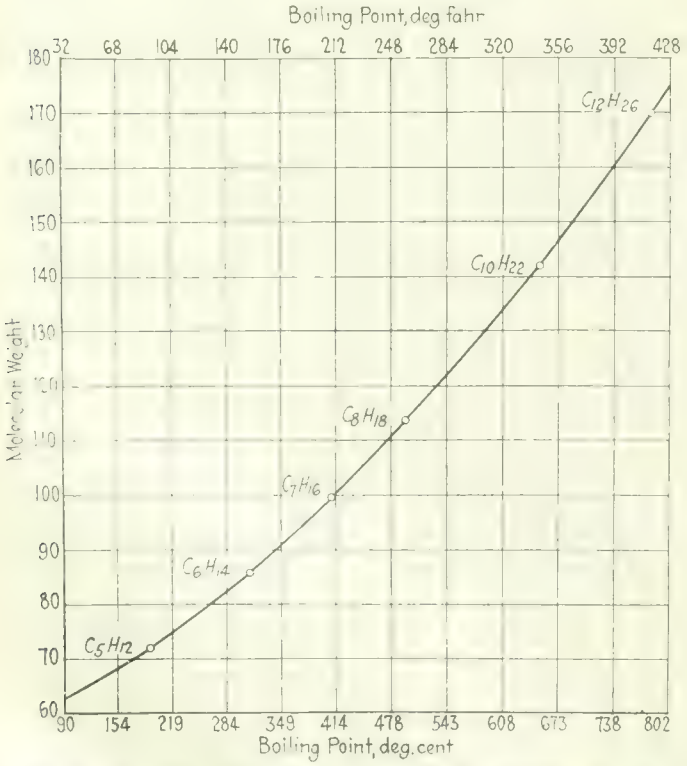

FIG. 3—RELATION BETWEEN THE MOLECULAR WEIGHT AND THE BOILING-POINTS FOR SATURATED PARAFFIN HYDROCARBONS

sure of 760 mm. (29.92 in.) of mercury.

A rather serious difficulty lies in the presence of comparatively large amounts of air dissolved in the liquid hydrocarbons. A rather novel method of correcting for this error has been devised by H. T. Tizard and A. G. Marshall. It is described in their recent report on the Measurement of Vapor-Pressures of Hydrocarbon Fuels[6]. However, their method is rather tedious in its manipulation, and the authors have found that, by cooling the vapor-pressure bulb to about 20 deg. below zero cent. (4 deg. below zero fahr.) by using ice and calcium chloride, and evacuating to a pressure of about 1 mm. (0.039 in.) of mercury with constant agitation of the apparatus, practically all of the dissolved air can be expelled from the liquid with an entirely negligible loss of the volatile constituents of the gasoline. The last traces are then swept out by allowing the temperature to rise until a very small amount of the liquid has been boiled off under low pressure.

The foregoing method gives results of sufficient accuracy for ordinary work. It is not to be recommended,

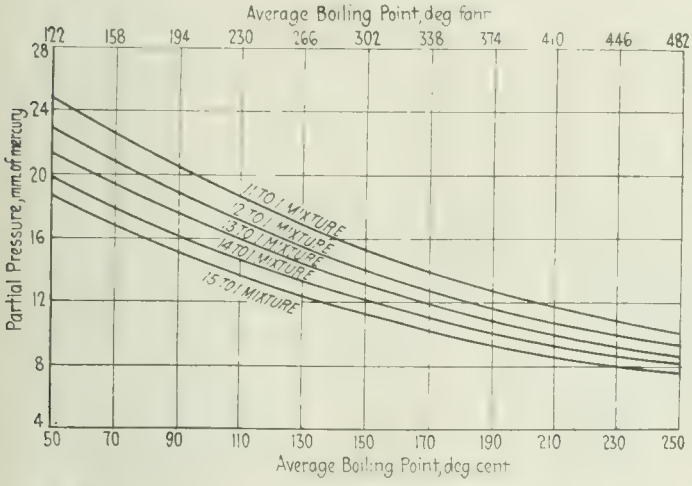
Average Boiling Point, deg fahr
122 158 194 230 266 302 338 374 410 446 482
28 24 20 16 12 8 4
Partial Pressure, mm of mercury
1:1 TO 1 MIXTURE
12 TO 1 MIXTURE
13 TO 1 MIXTURE
14 TO 1 MIXTURE
15 TO 1 MIXTURE
50 70 90 110 130 150 170 190 210 230 250
Average Boiling Point, deg cent

FIG. 4—CURVES SHOWING THE RELATION BETWEEN THE PARTIAL PRESSURES OF FUELS IN VARIOUS MIXTURES AND THE AVERAGE BOILING-POINTS

however, for work where the vapor-pressures are small, say below 10 mm. (0.394 in.) of mercury.

AVERAGE MOLECULAR-WEIGHT DETERMINATION

The method used by the authors in determining the approximate average molecular weights of the fuels for use in calculating partial pressures is explained fully in their previous article[7]. The accompanying curve, Fig. 3, is used for determining the molecular weights corresponding to the average boiling-points obtained from the differential distillation-curves. The authors hope to replace this by a direct determination of molecular weight, although the errors introduced by the above easy, though approximate, method do not affect the condensation temperature by more than 2.0 deg. cent. (3.6 deg. fahr.).

PARTIAL-PRESSURE CALCULATION

The partial pressures of the various fuels in mixtures with air were calculated after the following method for gasoline with an average molecular weight of 114 in a 12 to 1 mixture at a pressure of 1 atmosphere.

$$\text{Partial pressure} = 1/114 \div (1/114 + 12/29) \times 760 \text{ mm.}$$
$$(29.92 \text{ in.}) = 15.9 \text{ mm. } (0.626 \text{ in.})$$

[6] See *Journal of the Institution of Petroleum Technologists*, vol. 8, No. 31, p. 217

[7] See THE JOURNAL, November, 1921, p. 313.

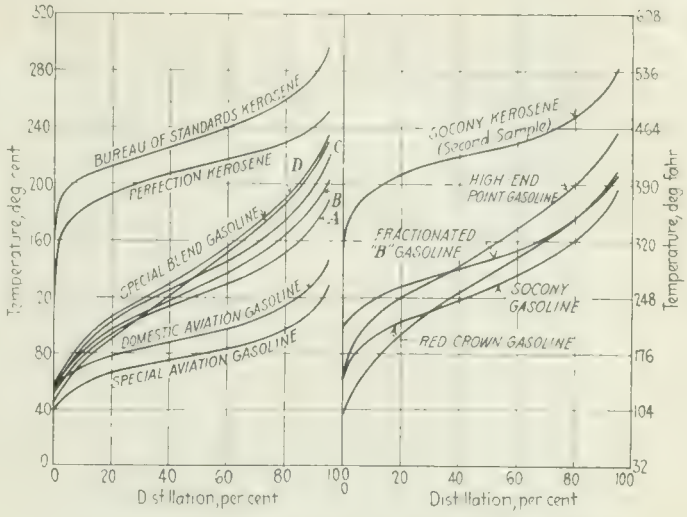

FIG. 5—DISTILLATION CURVES OF THE 14 FUELS TESTED

A chart has been constructed for convenience in use, shown in Fig. 4, in which the partial pressures of fuels in various mixtures have been plotted against their average boiling-points.

FUELS INVESTIGATED

As stated, the present paper embraces 14 fuels, including two of those covered by the original article. The results previously reported on the first fuel that was run, Socony kerosene, have been found erroneous, apparently due to failure to remove all the air from the flask or to leakage through the ordinary stopcock used at that time. The work on this fuel has accordingly been repeated, although, unfortunately, not enough of the original sample was at hand. The new sample that was procured, while corresponding closely, was not identical with the original fuel. The results on this second sample are recorded under the heading "Socony Kerosene, Second Sample." The distillation curves of the 14 fuels are given in Fig. 5, and the fuels themselves may be identified as follows:

(1) *Socony Kerosene*—A domestic kerosene marketed in New England by the Standard Oil Co. of New York; procured in a service-station in Boston

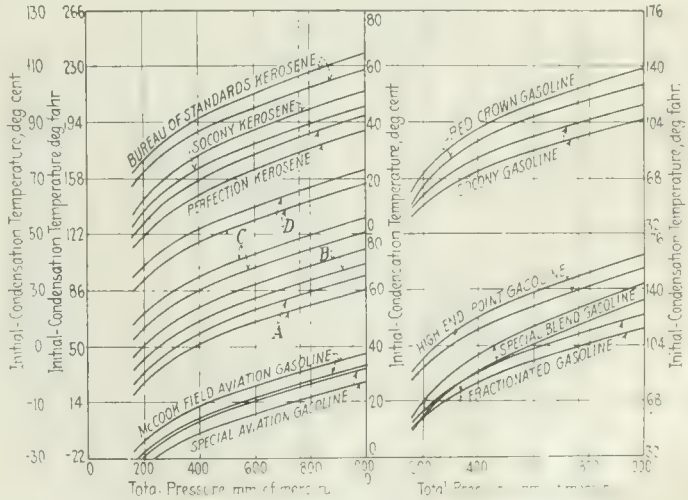

FIG. 6—CURVES SHOWING HOW THE INITIAL-CONDENSATION TEMPERATURES OF THE DIFFERENT FUELS VARY WITH CHANGES IN THE TOTAL PRESSURE

(2) *Perfection Kerosene*—A domestic kerosene marketed in the Middle West by the Standard Oil Co. of Indiana; sample supplied in 1921 by the Waukesha Motor Co.

(3) *High-Boiling Kerosene*—A sample of domestic kerosene procured at the Bureau of Standards, City of Washington; origin unknown

(4) *Socony Gasoline*—A motor gasoline marketed in New England by the Standard Oil Company of New York in 1921, and procured from a service-station in Boston

(5) *Red Crown Gasoline*—A motor gasoline marketed in the Middle West by the Standard Oil Co. of Indiana; sample supplied in 1921 by the Waukesha Motor Co.

(6) *"High-End-Point" Gasoline*—Socony gasoline to which was added 25 per cent of the first 50-per cent cut from distilling Socony kerosene

(7) to (10) *Four Fuels of Varying Volatility*:—Samples of fuels used for road tests carried on at the Bureau of Standards, City of Washington, under the cooperative fuel research program

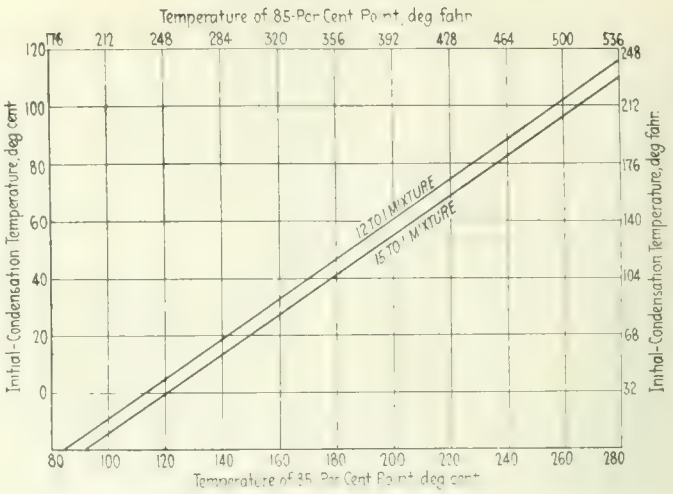
Temperature of 85-Per Cent Point, deg fahr
Initial-Condensation Temperature, deg cent
Initial-Condensation Temperature, deg fahr
12 TO 1 MIXTURE
15 TO 1 MIXTURE
Temperature of 85-Per Cent Point, deg cent

FIG. 9—VARIATION OF THE INITIAL-CONDENSATION TEMPERATURE WITH THAT OF THE 85-PER CENT POINT

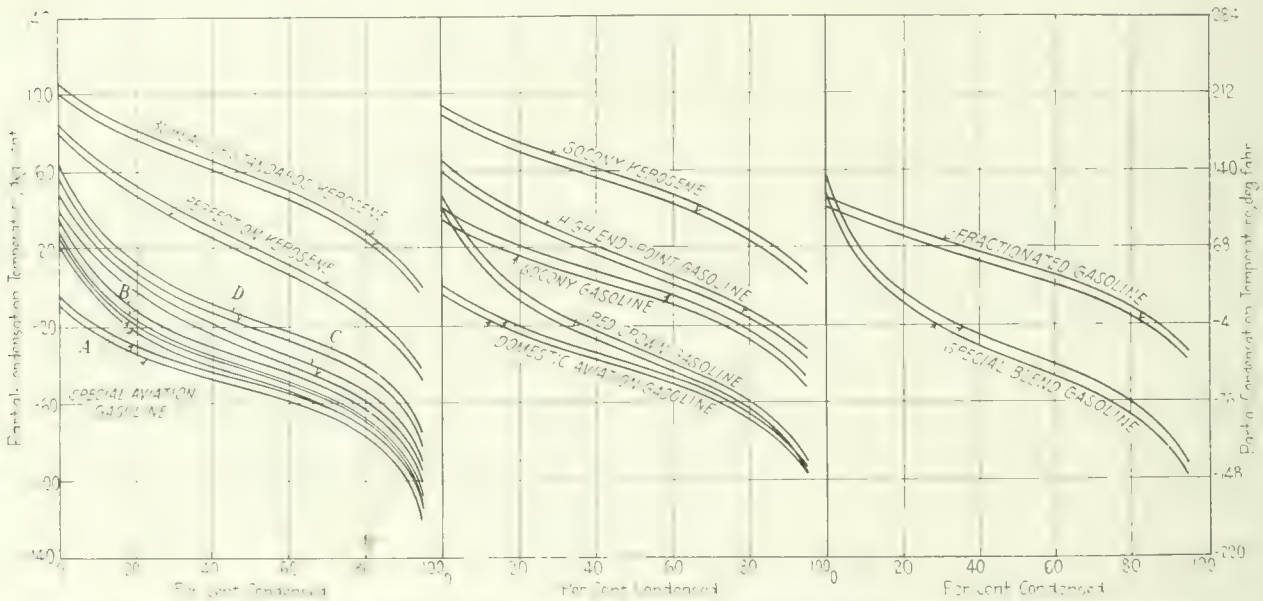

FIG. 7—CURVES GIVING THE APPROXIMATE PARTIAL-CONDENSATION TEMPERATURES OF THE DIFFERENT FUELS AT ATMOSPHERIC PRESSURE

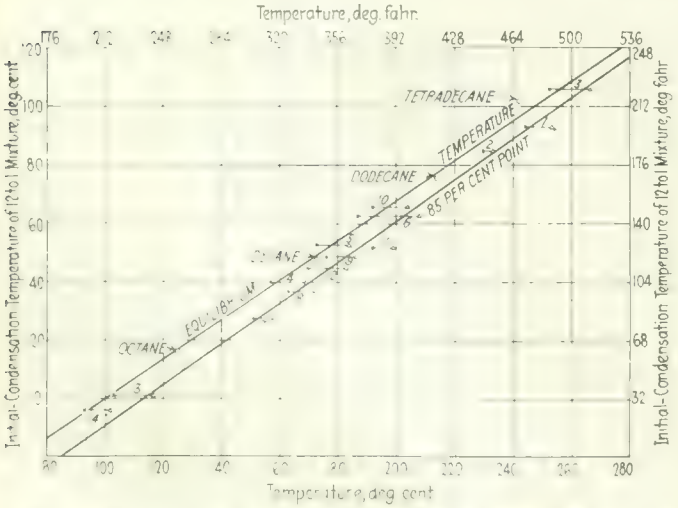

ILLUSTRATION OF THE DEW-POINTS OF MIXTURES OF VARIOUS [illegible] EQUILIBRIUM TEMPERATURE AND THAT CORRESPONDING TO THE 85 PER CENT POINT

(11) *"Special-Blend" Gasoline*—An artificial blend prepared in the laboratory to have a wider distillation range, but the same average boiling-point, as fuel *C* in test No. 9

(12) *Fractionated Gasoline*—A product obtained by distilling fuel *B* in test No. 8 through a fraction-

TABLE 1—DEW-POINTS FOR A 12 TO 1 MIXTURE

Plotted Against Distillation Points, Per Cent	Average Deviation		Maximum Deviation	
	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.
50	8.5	15.3	19.0	34.2
70	3.8	6.8	15.0	27.0
80	3.1	5.6	10.0	18.0
85	2.9	5.2	8.0	14.4
90	4.0	7.2	8.0	14.4
95	4.0	7.2	10.0	18.0
Dry Point	4.3	7.7	13.0	23.4
Equilibrium Temperature	3.0	5.4	10.0	18.0

TABLE 2—CHARACTERISTICS OF TYPICAL MOTOR FUELS[8]

No.	Kind of Fuel	Baumé Gravity Deg.	Specific Gravity	Distillation Data: Initial Deg. Cent.	Initial Deg. Fahr	50 Per Cent Deg. Cent.	50 Per Cent Deg. Fahr.	80 Per Cent Deg. Cent	80 Per Cent Deg. Fahr	90 Per Cent Deg. Cent	90 Per Cent Deg. Fahr	95 Per Cent Deg. Cent	95 Per Cent Deg. Fahr	Distillation Range Deg. Cent	Distillation Range Deg. Fahr	Average Boiling-Point Deg. Cent	Average Boiling-Point Deg. Fahr	Average Molecular Weight	Molecular Heat of Vaporization from the Vapor-Pressure Curve, Cal. per Gram Mol.	Temperature of: 760 mm. (29.92 in.) of Mercury Vapor Pressure Deg. Cent	760 mm. (29.92 in.) of Mercury Vapor Pressure Deg. Fahr	Equilibrium Solution at 760 mm. (29.92 in.) of Mercury Deg. Cent	Equilibrium Solution at 760 mm. (29.92 in.) of Mercury Deg. Fahr	Initial Condensation of a 12 to 1 Mixture Deg. Cent	Initial Condensation of a 12 to 1 Mixture Deg. Fahr	Initial Condensation of a 15 to 1 Mixture Deg. Cent	Initial Condensation of a 15 to 1 Mixture Deg. Fahr
1	Socony Kerosene, Second Sample	45	0.800	159.0	318.2	224.0	435.2	247.0	476.6	254.0	489.2	277.0	530.6	118.0	244.4	225.0	437.0	178	9,350	..	....	..	.	95.0	203.0	89.0	192.2
																			11,200	244.0	471.2	244.0	471.2	.	.	....	....
2	Perfection Kerosene	42	0.814	126.0	258.8	213.0	415.4	228.0	442.4	234.0	453.2	251.0	483.8	125.0	257.0	210.0	410.0	168	6,930	.	.	.	.	85.0	185.0	80.0	176.0
				134.0	273.2	230.0	446.0	246.0	474.8	249.0	480.2	270.0	518.0	76.0	168.8	228.0	442.4	180	10,700	227.0	440.6	230.0	446.0		.	....	.....
3	No. 3 Kerosene			168.0	334.4	233.0	451.4	258.0	496.4	266.0	510.8	296.0	564.8	128.0	262.4	233.0	451.4	184	7,770	....	....	..	..	105.0	221.0	101.0	213.8
				.	.	..	.	....	....	....	..	....	.	....	.....	....	..		11,750	251.0	483.8	252.0	485.6			.	.....
4	Socony Gasoline	60	0.743	60.0	140.0	128.0	262.4	160.0	320.0	169.0	336.2	196.0	384.8	136.0	276.8	128.0	262.4	115	7,510	....	.	.	.	40.0	104.0	34.0	93.2
				83.0	181.4	195.0	383.0	218.0	424.4	225.0	437.0	242.0	467.6	159.0	318.2	182.0	359.6	147	8,600	158.0	316.4	157.0	314.6		..	....	.....
5	Red Crown Gasoline	57	0.752	35.0	95.0	138.0	280.4	177.0	350.6	184.0	363.2	210.0	410.0	185.0	365.0	131.0	267.8	117	6,500	....	..	....	.	53.0	127.4	48.0	118.4
				85.0	185.0	185.0	365.0	211.0	411.8	224.0	435.2	253.0	487.4	168.0	334.4	184.0	363.2	148	7,450	175.0	347.0	173.0	343.4	....	.....	....	....
6	High End-Point Gasoline	57	0.752	62.0	143.6	154.0	309.2	150.0	302.0	208.0	406.4	236.0	456.8	174.0	345.2	147.0	296.6	126	7,550	.	....	.	.	63.0	145.4	58.0	136.4
				132.0	269.6	218.0	424.4	233.0	451.4	238.0	460.4	256.0	492.8	124.0	255.2	204.0	399.2	163	10,600	187.0	368.6	187.0	368.6	....	.....	.....	.....
7	Cooperative Fuel Research Gasoline — Grade *A*	62	0.727	49.0	120.2	121.0	249.8	151.0	303.8	160.0	320.0	170.0	338.0	121.0	249.8	121.0	249.8	111	5,100	..	.....	....	. .	28.0	82.4	24.0	75.2
				.	....	..	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	....	.	7,770	150.0	302.0	151.0	303.8	....	.....	.....	....
8	Grade *B*	61	0.733	52.0	125.6	126.0	258.8	164.0	327.2	174.0	345.2	202.0	395.6	150.0	302.0	125.0	257.0	114	5,400	.....	.....	....	.....	37.0	98.6	32.0	89.6
				.	.	.	.	.....	.....	.....	.....	.....	.....	.....	.	.	.	..	8,350	163.0	325.4	163.0	325.4	.....	.....	.....	....
9	Grade *C*	60	0.736	52.0	125.6	134.0	273.2	176.0	348.8	186.0	366.8	217.0	422.6	165.0	329.0	135.0	275.0	119	5,910	....	.....	.....	.....	49.0	120.2	44.0	111.2
				....	...	.	.	.	.	.....	.	....	.	.	.	.	.	..	8,800	176.0	348.8	176.0	348.8	....	.....	.....	.....
10	Grade *D*	59	0.740	54.0	129.2	139.0	282.2	191.0	375.8	202.0	395.6	234.0	453.2	180.0	356.0	142.0	287.6	123	6,520	.....	.....	....	....	66.0	150.8	60.0	140.0
				.	.	..	...	.	.	.	....	....	....	.	.	.	.	...	9,750	192.0	377.6	192.0	377.6	.	...	.	.
11	Special Blend Gasoline	59	0.740	45.0	113.0	134.0	273.2	188.0	370.4	199.0	390.2	231.0	447.8	186.0	366.8	135.0	275.0	119	5,780	....	..	..	..	52.0	125.6	48.0	118.4
				.	.	.	....	....	....	.....	....	..	.....	.	.	.	.	...	8,070	198.0	388.4	193.0	379.4	.	..	.	..
12	Fractionated Gasoline	.		36.0	96.8	146.0	294.8	168.0	334.4	182.0	359.6	208.0	406.4	112.0	233.6	147.0	296.6	127	7,830	..	..	....	....	45.0	113.0	40.0	104.0
				.	.	.....	...	....	....	....	....	....	....	....	....	....	..	...	8,900	170.0	338.0	170.0	338.0	.	..		
13	Domestic Grade Aviation Gasoline			53.0	127.4	93.0	199.4	111.0	231.8	116.0	240.8	133.0	271.4	80.0	176.0	94.0	201.2	97	6,280	...	..	..	.	1.0	33.8	4.0	24.8
				72.0	161.6	118.0	244.4	137.0	278.6	142.0	287.6	169.0	336.2	..			...	....	7,630	101.0	213.8	103.0	217.4			..	..
14	High-Volatility Aviation Gasoline	.	.	39.0	102.2	79.0	174.2	96.0	204.8	102.0	215.6	132.0	269.6	93.0	199.4	78.0	172.4	89	6,100	....	....	..	..	−4.0	24.8	9.0	15.8
		..	..	....	.	....	.....	....	....	.....	.....	....	..	..	...	....	..	....	7,160	93.0	199.4	93.0	199.4	..	.	..	.

[8]The second line of data for each fuel applies to the equilibrium solution of that fuel.

ating column, and retaining that portion coming over between 100 and 200 deg. cent. (212 and 392 deg. fahr.)

(13) *Domestic-Grade Aviation-Gasoline*—A sample obtained early in 1922 from McCook Field, Dayton, Ohio

(14) *High-Volatility Aviation-Gasoline*—A sample of a special aviation gasoline obtained at the Bureau of Standards, City of Washington

Results of Experiments

The results of the tests on the above fuels are presented in graphic and tabular form and are, for the most part, self-explanatory. Fig. 6 shows the variation of the initial-condensation temperatures of the various fuels with different total pressures. Two curves are shown for each fuel, the upper one representing a 12 to 1 mixture and the lower one a 15 to 1 mixture. Similarly, Fig. 7 gives the approximate temperatures of partial condensation for the different fuels at atmospheric pres- the true condensation-temperature for paraffin hydrosure. As in the preceding case, the upper line represents the 12 to 1 mixture.

It was pointed out in the previous paper[9] by the authors that, for the three fuels tested, the average boiling-point of the equilibrium solution approximated that of the 85-per cent point of the original fuel. It also appeared that by subtracting 135 deg. cent. (275 deg. fahr.) from the 85-per cent point, it would be possible to *approximate* carbon fuels. While such a rule could not be expected to hold with great precision for fuels of widely different boiling-point or width of cut, its convenience for many practical purposes was so great that one of the main objects of the work on the 14 fuels was to determine whether any such generalization could be drawn for a wider variety of motor-fuels. With this end in view, the dew-points of the various fuels were plotted against several points taken from the distillation curves, namely, the 50, 70, 80, 85, 90 and 95-per cent and dry points, and also against the equilibrium temperatures observed in preparing the equilibrium solution. The results are shown in Table 1.

It was found that, in general, the relationship between the dew-points of the various fuels and any of the above points on their distillation curves could be approximated roughly by a representative straight line, but that the average deviation of individual observations was very large in the case of the 50-per cent or end-points, while plotting against the 85-per cent points gave the most concordant results, the average deviation being only 2.9 deg. cent. (5.2 deg. fahr.). In Table 1 are given the average and the maximum temperature deviations when the dew-points are plotted against the various distillation temperatures. In Fig. 8 are shown the initial-condensation temperatures for 12 to 1 mixtures plotted against the 85-per cent points and the equilibrium temperatures in degrees centigrade. The horizontal lines joining pairs of points indicate the differences in temperature between the 85-per cent points and the equilibrium temperatures. Four points are also added to represent the calculated dew-points of four pure paraffin hydrocarbons, and the approximate agreement of even these "perfectly fractionated" fuels indicates the fundamental validity of the relationship found for the various commercial fuels.

It will also be noted that, while the rule of subtracting 135 deg. cent. (275 deg. fahr.) from the 85-per cent point is approximately correct for the average motor-fuel, it varies consistently between 160 deg. cent. (320 deg. fahr.) for high-boiling kerosenes to 110 deg. cent. (239 deg. fahr.) for very volatile aviation-gasoline. The simplest method of determining the correct value is, however, to determine the 85-cent point of the fuel and then refer to Fig. 9.

Rather surprisingly, the accuracy with which the dew-point may be determined from the 85-per cent point of the ordinary distillation curve, appears to be fully as good as when it is found by determining the equilibrium boiling point by the recommended method. In other words, it is apparently not worth while to prepare the equilibrium solution unless it is to be used for accurate vapor-pressure measurements as described by the authors. The determination of the equilibrium boiling point is, however, a simple matter, and the value for the dew-point found by referring to the upper line in Fig. 8 is a valuable check on that determined from the 85-per cent point by referring to the lower line in the same illustration. The average of the two should be correct within 2 or 3 deg. cent. (3.6 or 5.4 deg. fahr.).

One important corollary of the relationship between the 85-per cent point and the dew-point is that, in increasing the yield of motor-fuel by a closer fractionation of the crude, if a fractionated fuel is to have the *same effective volatility* as another fuel made by sample distillation, it should be made to have *the same 85-per cent point*, and hence *a lower end-point*, rather than trying to crowd in everything possible below the same end-point. This fact is, of course, tacitly recognized by the increasing emphasis on the 90-per cent point in motor-fuel specifications. This is practically as good as an 85-per cent point specification, and certainly far better than the over-emphasized end-point.

The results of all the experimental work to date have been summarized in Table 2.

[9] See The Journal, November, 1921, p. 313.

ADDRESSES OF MEMBERS WANTED

A FORCE is maintained in the offices of the Society at New York City whose sole duty is to keep the addresses of the members uptodate. A large number of changes of addresses are received each week by this department, and these are made promptly. In numerous cases the only notification which the Society has of a change of a member's address is a letter stating that The Journal, or some other communication, either was delayed in delivery or was not received at all. It is, of course, impossible for the office to have a correct list of addresses unless the members send in such changes promptly.

A list of the members for whom the Society has no correct address is given below. Communications sent to the last known business connection or mail address as it appears on the records have been returned to the New York office. Any one who can supply information regarding the present location of these members or offer any suggestions as to where their correct addresses can be obtained will confer a favor upon the Society by communicating with the Secretary at the New York office. It is only by the cooperation of the membership that a correct mailing list can be maintained and the members receive The Journal and other communications promptly.

Boggs, George. A.
Bruenauer, Otto
De Lorenzi, Ernest Adolph
Hewitt, Clarence C.
Magoffin, Charles F.
Miller, Lestere
Morton, R. B.
Smith, George W.
Ver Linden, Edward
Willard, Charles F.
Wissel, Ernest J.

Special Notice

TRANSACTIONS, PART II OF VOL. 16 (1921).

To Those Who Paid Dues for the Last Half of the Fiscal Year Beginning Oct. 1, 1920:

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Date S.A.E. Member

Research Foundation for the Economic Theory of Highway Improvement

By W. K. Hatt[1]

At the meeting of the Society of Automotive Engineers at West Baden, Ind., a joint committee of automotive and highway engineers was authorized to study the mutual relations of the vehicle and the road. Since that time the need for scientifically determined data has been growing, not only as a basis for mechanical relations, but as a guide to wise legislation.

Men seem unanimously in favor of research in general, and any proposal for attack upon the outstanding problems through research methods is received with approval. However, to organize the proposed research, to secure the resources for its prosecution and to find available men for the actual operations is not so easy.

But lying back of even these preliminaries is a common understanding of the objectives of such research and a mutually agreed upon allocation of the fields of operation. There is an inertia to human mentality, and such common understanding and purpose apparently requires growth in time. Happily, the automotive and the highway engineers have joined together for the purpose of fruitful research. At a meeting in New York City not long ago, attended by representatives of the automotive engineers, the highway engineers, and the motor-vehicle builders, an understanding was reached on the following outline of necessary research which was designated as a program upon which efforts would be concentrated. Activities in this program are not academic, but vital to the treatment of grave questions now pressing upon the public mind.

RESEARCH FOR THE AUTOMOTIVE ENGINEER

By laboratory tests to determine

(1) Fuel, oil and grease consumption and power development of the vehicle, and from these to calculate the performance on various surfaces and grades and the excess power for moving trailers. (See Bulletin of Michigan State Highway Department on Experiments by Prof. W. E. Lay.)
(2) To study the effect of improved grades on the design of the powerplant of the vehicle
(3) To consider the design of the vehicle to impose on the road the minimum loads for specified capacities of vehicle
(4) To study the lighting system of automobiles with a view to safety and the mechanisms indicating intentions of the driver

RESEARCH FOR THE HIGHWAY ENGINEERS

(1) To find rolling and air resistance of motor vehicles at various loadings and speeds on types of road surfaces and curves; limit of adhesion
(2) To determine the loads imposed on road surfaces by various vehicles, with various tire equipment at various speeds
(3) To discover the stresses and strains acting in various road surfacings under the expected loads and the properties and improvements of subsoils
(4) To determine the capital and maintenance costs resident in the road
(5) To determine the laws governing the increase of highway traffic by basic surveys of flow of traffic in typical regions

RESEARCH FOR NATIONAL AUTOMOTIVE CHAMBER OF COMMERCE AND AUTOMOBILE ASSOCIATIONS

(1) To assign schedule cards to a selected group of, say, 200 passenger drivers for each condition, to obtain operating expenses on the average for
  (a) Three classes of car
  (b) Regional conditions
    Macadam and gravel roads
    Dirt roads
    Paved roads
  (c) Topography
    Level
    Hilly
(2) To study records of truck and passenger bus fleets to obtain similar data

LOCATING HIGHWAY ENGINEER

Given the road resistance, the power available at the wheels, the speeds, the fuel, oil and grease consumption, the tires, the repairs, the driver's time, the depreciation, the overhead, and the expected traffic

To find the relation between the capital costs of the construction and operating expenses on roads of various surfaces and grades, length and rate

FEDERAL AGENCIES

(1) To study the movements of commodities and passengers by the highway and the railroads in the interest of coordination of transport
(2) To study the financing of highway improvements in the light of experience and science in related fields of the financing of public improvements
(3) To study the effect of highway improvemets on regional industries
(4) To study the effect of highway improvements upon the general productivity of men and industries

ADVISORY BOARD ON HIGHWAY RESEARCH

To evaluate the progress in the several fields of highway research by an analysis of completed and current projects; to outline needed researches; to assist existing organizations to correlate their work in the light of a comprehensive program; and to publish bulletins of information on methods and technique of research, and on progress in the several fields

It will be noticed that in this program the usual experiments on road resistance have been definitely divided as between the automotive and the highway engineer. This proposal is the result of a gathering held at the National Research Council in the City of Washington on July 14, 1922, at which the following report was adopted:

TRACTIVE RESISTANCE OF MOTOR VEHICLES

Rolling-Resistance is the resistance to translation arising from the interaction of the road and the vehicle, but excluding the resistances in the engine and transmission system.

[1] Director of the advisory board on highway research National Research Council, City of Washington.

Explanatory Note. — As ordinarily measured, this includes wheel-bearing resistance, which in the case of well-conditioned cars should not exceed 5 lb. per ton. Rolling-resistance by the definition also includes the resistance in the framework and spring-suspension system of the vehicle arising from the road. Rolling-resistance as measured contains various degrees of impact and road displacement effects depending upon the condition of the road and the design of the vehicle. The resistance due to the horizontal curvature of the road should be measured in the experiments.

Note.—It is the purpose of the tests of rolling-resistance to determine the force at the rear axle or the tire periphery necessary to move the vehicle, as conditioned by the road surface, the type of road, the tire equipment, the class and the weight of the vehicle, etc.

Air-Resistance is the resistance arising from the relative velocity of the air and the vehicle.

Explanation.—Ordinarily this resistance is included in the tested resistance, and should be subtracted to obtain the rolling-resistance. Investigations are needed to determine the law and the coefficient of this resistance for various vehicles.

Rolling and air-resistances are those resistances determined when a vehicle is towed with the power transmission mechanism disconnected from the driving-wheels. However, the difference between a self-operated and a towed vehicle in respect to tire losses and slipping may make some difference in results, especially at high speeds.

Note.—Having the rolling and the air-resistance, it becomes the function of the automotive engineer to design an efficient vehicle to furnish power for economical transportation over various alignments.

Transmission-System Resistance is the force required at the rear axle or the tire periphery to overcome all internal resistance from the clutch to the rear axle.

The transmission-system resistance depends upon the gear-ratio in mesh and the power transmitted, as well as upon other conditions, such as the speed, the temperature of the lubricant, etc. These losses are best determined in the laboratory.

Engine Resistance is the force required at the rear axle or the tire periphery to overcome the resistance of the engine, including the cooling system, fan and accessories.

Engine resistance depends upon the operation of the engine as regards the throttle opening, the speed, the temperature and the mechanical condition of the engine. These resistances are best determined in the laboratory.

Equipment and Instruments.—Rolling and air-resistance should be measured for basic types of motor vehicle and of tractor. For purposes of comparison of the economy of types of road, expressed in fuel-consumption, the time of translation and other costs of maintenance of the vehicle and the road, the rolling-resistance should be measured to an accuracy within 5 per cent.

The present state of the art indicates that at low speeds up to 10 m. p. h. a traction dynamometer of the liquid-pressure type, or a space-time recorder, is considered best fitted. At higher speeds, a space-time recorder, or a U-tube accelerometer, is most satisfactory. New instruments should be investigated, especially the torsion dynamometer.

Tests should be made of the adhesion of the tires to the road surfaces under running conditions to determine safety against skidding under various conditions of brake and tire equipment and road. The use of an accelerometer with locking of brakes is recommended.

Relation of the Automotive to the Highway Engineer

The automotive engineer needs data on the rolling and air-resistances rather than data on the gasoline consumption from road tests, since the latter depend upon the individual characteristics of the vehicle used, the carbureter, the habits of the driver, etc. Having the power factors, the automotive engineer will design the plant to furnish the power required.

From the standpoint of the highway engineer, a problem like the following is set:

A reduction in the grade of 4 ft. will reduce the amount of energy required by 8,000 ft-lb. What will this be worth in the saving of gasoline and the other operating expense for the traffic considered? Will the solution be for cars as at present built, or for cars using the roads 15 years from now? The mutual relation of the highway and the vehicle is expressed in the effect of low grades on changes in the engine design and the power requirements of the car. Inasmuch as the large expense of highway transportation is in the expense of operation of transportation rather than in the fixed charges and the maintenance of the road, the investigation of the costs of operation of traffic is particularly needed.

The fuel cost and time required, as affected by the type and the design of the surfaces and the grades, are measurable by experimental methods, and the depreciation of the vehicle and the other maintenance costs should be evaluated from a study of the statistics of motor vehicles obtained in actual operation.

In other words, it is considered practicable to determine the road performance of the vehicle from tests made in the laboratory combined with data on the rolling and the air-resistance. It appears that the available data from the several investigations of rolling-resistance will define the limits of this resistance for the various classes of road with a sufficient degree of accuracy for the purpose in view.

The subjects listed in (2) and (3) under the heading Research for the Automotive Engineer will no doubt suggest that there will be opportunity for productive research in these fields for some time to come. A study of the lighting systems of automobiles, mentioned in (4), cannot be delayed if current legislation is to be based upon physics rather than on ideas.

The highway engineers have planned to carry out item (2) in their section of the program in the early summer months. It is the opinion of some that data on item (3) have accumulated to such an extent that the services of the analyst are needed more than further experiments of large magnitude. Data of maintenance costs, item (4), are largely wanting. With reference to (5) the laws governing the increase of highway traffic should be known for a wise planning of road development. The only study of outstanding quality and quantity is that by Dean A. N. Johnson, of the University of Maryland, covering the development of traffic in Maryland.

I understand that the American Automobile Association is cooperating with the committee on the economic theory of highway improvement of the National Research Council in an endeavor to obtain average values of the operating expense of passenger cars.

The remaining sections of the program of research contain titles that define general research of a more difficult character, but the outcome of which would be basic in highway development.

Military-Airplane Development and Construction in Peacetime

By F. H. Russell[1]

Annual Meeting Paper

THE reconstruction period since the war has served to establish aviation as an essential arm of both the military and the naval forces of the Government. This in itself is a real accomplishment. But for several reasons the airplane industry has not performed the service that was expected of it and has not received the support that is necessary for its existence. Although the expense is great, the development of aviation through the facilities at McCook Field and at the Naval Aircraft Factory has been hampered by red-tape and by the fact that the personnel of the Government agencies are at the same time the judges of new developments and the competitors of the engineers in the industry. The result is a feeling of reticence among civilian engineers with regard to disclosing and developing new ideas, the retarding of the advancement of service types, and slow deliveries. Although several companies at the close of the war were well equipped to produce airplanes cheaply and efficiently, these gradually have been driven out of existence and their places have been taken by smaller organizations that depend solely on casual orders which return small profits.

Competitive bidding has resulted in delay to the Government and loss to the manufacturer; in some instances bids have been asked on machines that had not been sufficiently developed to allow the Government to furnish blueprints, design data or a bill of material. The safety of the Nation is predicated on a dependable source of supply of equipment, especially aircraft. An important function of the Government, therefore, is to see that the engineering and production data are complete, uptodate and practical. This is not usually the case, the contractor being depended upon to complete and correct the data; and an unforeseen loss of time and money has been entailed. Early development of the art of aviation was due to the genius of a few men, but the development of the future will be by organization, with specialists in every line; the production of the world's fastest airplane at the races in Detroit is a case in point. Confusion has arisen through the custom of ordering new types in small quantities and of depending on competitive bidding for the further supply, on the assumption that when once completed the article was "commercial" and not proprietary.

The suggestion is made that the experimental work and the subsequent developments be confined to the same organization, with provision for production in large quantities in time of war. The Government's problem should be the selecting of airplanes for training and operating, and the guiding of the industry in developing such designs. Engineering and production should go hand-in-hand. Government subsidies, such as are customary in other countries, are not needed yet but production must be encouraged through the supply of Government equipment. Particular types of airplane should be considered proprietary, but the Government should be free to purchase any design at any time in any stage of advancement and place it by competition or assignment with recognized units in the industry.

Cross-licensing, originated as a war concession by patent owners, has had the effect of causing some persons to feel that any airplane should be purchased by open competitive bidding. But this agreement did not contemplate encouraging one manufacturer to use another's design or standardizing construction so that it could be used by all. Competitive bidding should be used only when a producer has been found incompetent or unwilling to furnish his product at a reasonable price under reasonable conditions. Considering each type of airplane as proprietary would make for permanence of business, encourage small companies to increase their facilities and guarantee to the Government a source of supply in time of peace and the distribution of data and personnel in time of national need.

It may seem somewhat trite to suggest that in time of peace we should prepare for war. The possibility remains, however, that amid the pressing detail of individual problems we may lose sight of the necessity for maintaining a healthy aeronautic industry. A review, therefore, of the situation, as it appears at the beginning of 1923, may prove of value and awake an interest among those intimately connected with this problem so that our usefulness shall be increased.

During the four years that have elapsed since the war, aviation has established itself as an essential arm of both our military and naval forces. The experiments and operations carried on by the Air Service of the Army and the Bureau of Aeronautics of the Navy Department are entirely responsible for the important place that aircraft occupies in the military plans of our General Staff and the General Board. This in itself is a very real accomplishment.

It is felt, however, that during this constructive period the airplane industry has not performed the service that was to be expected of it; nor has it received the support essential to its very existence. Considerable effort has been expended by both services in endeavoring to establish a system by which new types of aircraft might be developed and a method by which their supply for current requirements might be secured. Government purchases must be made in accordance with the provisions of the appropriation acts, together with existing regulations, but these, although satisfactory for the procurement of commercial articles, do not lend themselves easily to the engineering problems of new development and small production.

The Air Service has attempted to solve the problem of development through the maintenance and the increase of facilities in its engineering division at McCook Field, and the Bureau of Aeronautics for the Navy has maintained the Naval Aircraft Factory at Philadelphia, not only for repairing existing equipment, but for constructing small quantities of experimental types. The cost of maintaining these two organizations has well-nigh exceeded the entire expenditure for aeronautical equipment in the aircraft industry since the war.

The actual development and construction of aircraft by these agencies places the Government in a position in which its personnel not only are the judges and experts

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of new development, but are themselves competitors of the engineers in the industry. While the individual officers have, it is believed, cooperated with the industrial units to the best of their ability, the fact, nevertheless, remains that among civilian engineers a feeling of reticence exists in the matter of disclosing and developing new ideas, which discourages the free intercourse that should exist between the user and the designer.

Old Designs and Slow Delivery

The development of new types by the industry, under the present restrictions, which have seemed necessary when dealing with many of the factories not properly manned and equipped, has been unreasonably slow and has retarded the advancement of service types in both the Army and the Navy. The Army is now receiving deliveries of a pursuit airplane for service use that was exhibited originally in the Aeronautical Show in 1919!

Investigation indicates that, of 117 ships delivered to the Navy during the fiscal year ended June 30, 1922, 52 emanated from the Government factory at Philadelphia, 17 from foreign sources and but 37 from the entire American aircraft industry.

A review of the designing and manufacturing units in the industry at this time will disclose even more clearly the seriousness of this situation. At the close of the war several well-organized companies were producing airplanes cheaply and efficiently. It would be supposed that with the reduced requirements of the Government we might have relied on the principle of the survival of the fittest to maintain and support the organizations best equipped to carry on the supplying of aircraft material. This, however, has not been the case. Among the larger companies the results of operating have been expressed from year to year by red figures in their balance sheets, and have driven and are today driving out of the business well-established, well-manned and well-financed factories, leaving in their places an increasing number of smaller units devoted particularly to developing whatever engineering order may be secured from time to time, with little regard to the permanency of their existence. The small engineering development orders given by the Government to such organizations generally have produced small profits. The further production, however, under competitive bidding by the larger units, of the machines thus developed, has resulted in delays to the Government and in serious losses in almost every case to the manufacturer. So-called production orders for from 25 to 50 machines have been offered to the industry from time to time by the Government for competitive bidding, when the machine itself was not sufficiently developed even to allow the Government to furnish blueprints, design data and bills of material that it could guarantee as correct. In a recent competition complete production drawings did not exist and there was no physical sample of the airplane available for the prospective bidders to study in making their estimates. Competitive bidding on airplane contracts has degenerated into a reckless gamble among desperate producers, who are willing to take any chance to obtain a contract and keep operating, and rely either on the mercy of the Government or on the appearance of an enthusiast in the rôle of a fairy godmother to meet the financial loss when it arrives. This explains why, in the instance above referred to, the bids of about a dozen producers ranged from less than $500,000 to nearly $1,250,000. This is not competition; it is nothing but industrial suicide. A continuance of this way of distributing business will destroy the industry.

The plans of our military forces on which the safety of the Nation depends in time of war must be predicated on a dependable source of supply of the equipment to be used. This is especially true in the matter of aircraft, which at present has no market worth considering except that of supplying the Government. It devolves, therefore, upon the Government to see that every dollar spent for construction is used to maintain the industry and render it capable of expanding.

There was a period in the development of the art when its advance was due directly to the individual genius of various men whose names may well be recorded as pioneers. It is believed that their work has been largely accomplished, and that the future development of the flying machine, for military or commercial purposes, will be brought about through the unceasing efforts of groups of engineers, each a specialist in his line, cooperating in one commercial organization for the production of the type desired. The results of the 1922 speed races at Detroit are an example. In this competition an opportunity was given to design and construct machines of various types under both methods of development. The world's fastest airplane was not the product of a single genius, but rather the result of the properly directed efforts of assistant engineers, each of whom was an expert in some branch, such as aerodynamics, power, radiation and strength of materials. In the design and construction of this airplane the Air Service made an exception to its general custom of requiring submission and approval of each individual detail, and insisted only that the strength factors be maintained and that the guaranteed speed be delivered in a practical airworthy machine. The result was that the engineers, having a free hand and a real responsibility, rose to the task, and the machines were designed and built in 90 days, whereas under ordinary service regulations more than a year would have been required to complete them.

Through the effort to maintain the industry there has arisen a confusion of ideas with reference to the creation of a type and the production of it in small quantities under so-called production contracts. The custom of ordering new types from a creative organization in quantities of one, two or three, or even ten or twenty, and then depending upon open competitive bidding for further supply on the assumption that the engineering problem had been completed and that the article was "commercial" and not proprietary, has failed to furnish the Government with airplanes promptly and to sustain the manufacturer.

It is believed that the design of a new type and its subsequent development should be placed with one organization, which, having created the experimental article, should be expected to supply it in such quantities as might be required for peacetime operation. The necessity for reproducing it in large quantities for war use must be considered as important a factor in the design as is the actual aerodynamical efficiency of the machine itself. This requirement has not received the attention it deserves by either the Government or the civilian engineer.

The Government's Peacetime Problem

The peacetime problem of the Government engineer clearly is, first, the selection of the types of airplane that are required for actual military training and operations; and, secondly, the guidance and support of the industry toward the developing of such designs, having in mind constantly that the airplane developed must not only be satisfactory for the service desired, but be designed in detail so that it will be capable of quantity reproduction.

Both the Air Services and the units in the industry

should thoroughly appreciate that, to be effective in service, civilian aircraft organizations must consist not only of a capable group of creative engineers, but also of men trained and experienced in production manufacturing; that the physical facilities should include not only wind-tunnels and aerodynamic, physical and chemical laboratories, but also the latest types of production machinery; and, further, that such an organization should have sufficient financial resources to sustain it when operating as a complete unit. Any separation of engineering from production, such as is found in the types of airplane developed by small engineering units, or of production from inadequate creative engineering, is bound to result disastrously. The two must go together, and the Government must establish a policy which, under proprietary orders, a company may specialize in the development of one design or class of machine, build it continually in small quantities and constantly improve it. Such an organization should be required at the same time to supply standardized blueprints, specifications, bills of material, and the like, which, in time of national emergency, could be placed at once in the hands of constructors outside the industry for quantity production.

It should not be inferred from these suggestions that the business of supplying the United States Government with aeronautical material should be centralized among any favored few. This, of course, would not only be contrary to our way of doing things, but certainly would retard growth. On the other hand, it is believed that the aircraft facilities of the Country should be surveyed very carefully by the purchasing branches of the Air Services, with the idea of ascertaining both what units and how many they can support with the funds and projects available, and then encourage the units that most nearly meet the requirements.

It must be realized that European countries are approaching this problem from another point of view. England, France and many other countries are subsidizing commercial aeronautics, and thus are encouraging production, while in this country we have not yet been able to get the Congress even to give us a law to regulate air navigation. We do not need subsidies yet, but we must sustain healthy production units through the supply of Government equipment.

An airplane of a particular type should be considered a proprietary article. No one, either within the Government or without, would consider an automobile of any one type, such as the Pierce-Arrow, for example, so commercial as to be procured by competitive bidding on the open market. Aeronautical engines are not so considered by the Government. To protect itself, the policy of the Government is to develop two or more types of engine for each service required. The same policy should prevail in the supply of airplanes. The suggestion often has been made that the allocation of work under types that an organization is particularly qualified to supply would prevent the Government from using to advantage the genius of individual inventors and engineers. This is not the case. The Government should be free to purchase at any time a design, in whatever stage of completion it finds to be advantageous, from anybody, and then to place it through competition or by assignment with the recognized units in the industry. It should not expect to obtain a practical production airplane from an individual or from a small organization, but should use its efforts at all times to bring individual engineering ability into existing civilian organizations, and not encourage the formation of new companies whenever a new design is to be considered.

Cross-Licensing

One reason that many persons have come to feel that any company could build any airplane, and that the Government should purchase airplanes only through open competitive bidding, as it would any other commercial article, is the fact that all of the principal aircraft patents are cross-licensed under the Manufacturers Aircraft Association, for membership in which any aircraft contractor to the Government is eligible. This cross-licensing agreement, originally a war concession by the patent owners to the Country, in order that the Government might not be restricted in any manner in developing its sources of supply, has been of the greatest value to the industry in opening practically to all the opportunity to use any patented improvement.

This agreement, however, did not contemplate the encouraging of one manufacturer to build from another's specific design, or suggest that the construction of aircraft was so standardized as to make any design capable of reproduction by all. Non-exclusive patent rights are granted to all members, but design rights are subject to individual negotiation.

Competitive bidding on design should be used by the Government only in cases where the producer has been found incompetent to supply or unwilling to furnish his product at a reasonable price under reasonable conditions. Each type of aircraft must be considered as proprietary. Such a policy would make for permanence of business and encourage individual companies to increase, or at least to sustain, their present facilities; guarantee to the Government a source of supply in time of peace, and assure the practical distribution of both manufacturing data and skilled personnel among other industries requisitioned to aircraft production in time of need.

For four years the industry has cooperated with the Government agencies in every possible way, endeavoring itself to survive at the same time. The point has now been reached where we can see clearly the destructive elements in the present Governmental policy, and it is the duty of the Government to amend its system so that the aircraft industry may be ready at any and all times to meet a national emergency. It is hoped that the public never again will be able to accuse us of unpreparedness, inefficiency or incompetency.

A New Interpretation of Exhaust-Gas Analysis

By E. H. Lockwood[1]

GASES of combustion may be analyzed conveniently by the standard Orsat apparatus. Its uses are limited, however, to cases where the combustion is nearly complete, leaving no unburned fuel except small amounts of carbon monoxide. Fortunately this condition generally is complied with where solid and liquid fuels are used, as in boiler furnaces and internal-combustion engines. In the testing of such powerplants, the Orsat apparatus may contribute results of much value as regards the efficiency of combustion.

It will be unnecessary at this time to describe the Orsat apparatus, but reference may be made to its general method of operation. The first step in the analysis is to draw exactly 100 cubic units of the gas into a cylindrical glass tube, where volumes can be measured by a scale etched on the glass. The gas sample is then passed successively into three chambers, where it comes into contact with chemicals that absorb the different components of the gas. After each absorption the sample is returned to the graduated cylinder, where the loss of volume is read in percentage on the scale. The components found in this way are carbon dioxide (CO_2), oxygen (O_2) and carbon monoxide (CO). Finally, their sum is subtracted from 100 and the remainder is assumed to be nitrogen (N_2). A complete flue-gas analysis consists of the four items just mentioned, the sum of which is always 100. The carbon monoxide item is usually small and may be zero. The nitrogen item is always large, say, 80 per cent of the total.

After the completion of the analysis the results must be interpreted. This usually is done by elementary chemical arithmetic, based on the combining formulas for carbon dioxide and monoxide, the atomic weights of the elements, and the proportions of oxygen and nitrogen in the air. The arithmetical method determines the weight of air used in the combustion of the carbon, but fails to reveal the amount used by the hydrogen in the fuel. The latter must be determined by a supplementary computation based on the amount of hydrogen in the fuel.

The arithmetical computations are fairly simple, but the constants are easily forgotten unless used frequently. To avoid the drawbacks of the chemical theory, algebraic formulas have been devised for producing the same results by simple substitution of the gas-analysis percentages and for solving the equation. The following formulas have been widely used for this purpose:

$$\text{Air per pound of carbon} = 3.03\,N_2 \div (CO_2 + CO) \quad (1)$$

$$\text{Dry gas per pound of carbon} = \{\,11\,CO_2 + 8\,O_2 + 7\,(N_2 + CO)\,\} / 3\,(CO_2 + CO) \quad (2)$$

$$\text{Ratio of the air actually used to the air theoretically required} = N_2 / \{\,N_2 - 3.78\,(O_2 - CO/2)\,\} \quad (3)$$

Formula (1) is usually credited to Dr. D. S. Jacobus and (2) to R. S. Hale. All are deduced in Gebhardt's Steam Power Plant Engineering. They are examples of ingenious reasoning, because they take into account the air required by the hydrogen in the fuel as well as by the carbon. The drawback lies in basing the various quantities on the carbon in the fuel, whereas it is much more convenient to use the combustible in the fuel. The reason is that the combustible is given by the simple proximate analysis, which is the sum of the fixed carbon and the volatile matter, while the carbon is given by the ultimate analysis, which is relatively costly and rarely available.

A modification of the formulas, based on combustible, can be easily made. Furthermore, by a logical extension of the reasoning, formulas can be derived for the proportions of carbon and hydrogen in the fuel, for the water vapor formed by combustion, and for the theoretic air required for the combustion of the fuel. I offer my formulas for the consideration of those interested. Before stating the new formulas, it will be in order to mention certain limitations that apply alike to the old and to the new formulas. First, the formulas apply only to fuels that contain negligible amounts of nitrogen. Fortunately this includes the ordinary forms of coal and liquid fuels. Secondly, the sulphur in the fuel is also assumed to be negligible in amount. Thirdly, the term hydrogen refers to the so-called free hydrogen, H — (O/8), or the portion of the hydrogen that requires air for its combustion. The derivation of the formulas, which are given below, will be omitted here and placed in an appendix, as the explanation is rather technical.

$$\text{Air per pound of combustible} = \frac{18.3\,N_2}{0.525\,N_2 + 5\,CO + 4\,CO_2 - 2\,O_2} \quad (4)$$

$$\text{Dry gas per pound of combustible} = \frac{22\,CO_2 + 16\,O_2 + 14\,(N_2 + CO)}{0.525\,N_2 + 5\,CO + 4\,CO_2 - 2\,O_2} \quad (5)$$

$$\text{Theoretical amount of air per pound of combustible} = \frac{18.3\,N_2 + 34.8\,CO - 69.6\,O_2}{0.525\,N_2 + 5\,CO + 4\,CO_2 - 2\,O_2} \quad (6)$$

$$\text{Percentage of excess air} = \left[\frac{69.6\,O_2 - 34.8\,CO}{18.3\,N_2 + 34.8\,CO - 69.6\,O_2}\right] \times 100 \quad (7)$$

$$\text{Water vapor per pound of combustible} = \frac{4.77\,N_2 - 9\,CO - 18\,(CO_2 + O_2)}{0.525\,N_2 + 5\,CO + 4\,CO_2 - 2\,O_2} \quad (8)$$

$$\text{Percentage of carbon in combustible} = \left[\frac{6\,(CO_2 + CO)}{0.525\,N_2 + 5\,CO + 4\,CO_2 - 2\,O_2}\right] \times 100 \quad (9)$$

$$\text{Percentage of hydrogen in combustible} = \left[\frac{0.525\,N_2 - CO - 2\,(CO_2 + O_2)}{0.525\,N_2 + 5\,CO + 4\,CO_2 - 2\,O_2}\right] \times 100 \quad (10)$$

$$\text{Ratio of carbon to hydrogen in combustible} = \frac{6\,(CO_2 + CO)}{0.525\,N_2 - CO - 2\,(CO_2 + O_2)} \quad (11)$$

The term combustible refers to the sum of the fixed carbon and the volatile combustible matter, as given by the proximate analysis. Or, it may be stated as the total weight of fuel less water and ash. In applying the formulas, the percentages of CO_2, O_2, CO and N_2 are inserted for the symbols and solved in the usual way.

It will be noted that the new formulas contain information not hitherto deduced from the flue-gas analysis, namely: water vapor in the gases of combustion and the proportions of carbon and hydrogen in the fuel. These items are to be regarded as only supplementary to the main object, which is to determine the weights of air and of the dry gases, as given by formulas (4) to (7).

Internal evidence of the consistency of the formulas and of the gas analysis may be had by summing up the weight of the products in two ways: first, 1 + air (4); second, dry gas (5) + water vapor (8). The two sums should be the same for consistency. A rigid check of the new formulas

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can be had from the ultimate analysis of the fuel, which permits exact computation of the theoretic air and of the ratio of hydrogen and carbon.

In conclusion, two illustrations will be given of the use of the formulas in interpreting gas analysis.

Example 1.—Semi-bituminous coal in a power boiler. Flue-gas analysis: $CO_2 = 11.8$; $O_2 = 7.7$; $CO = 0.2$; $N_2 = 80.3$.

	By Formula	
Air per pound of combustible	(4)	19.4 lb.
Dry gases per pound of combustible	(5)	20.0 lb.
Theoretic air per pound of combustible	(6)	12.7 lb.
Excess air used	(7)	54.0 per cent
Water vapor per pound of combustible	(8)	0.4 lb.
Carbon in combustible	(9)	95.6 per cent
Hydrogen in combustible	(10)	4.4 per cent
Ratio of carbon to hydrogen	(11)	21.8

Example 2.—Gasoline in a six-cylinder engine (1917). Exhaust-gas analysis: $CO_2 = 10.15$; $O_2 = 0.55$; $CO = 5.65$; $N_2 = 83.65$.

	By Formula	
Air per pound of combustible	(4)	13.65 lb.
Dry gases per pound of combustible	(5)	13.2 lb.
Theoretic air per pound of combustible	(6)	15.1 lb.
Excess air used	(7)	—9.5 per cent
Water vapor per pound of combustible	(8)	1.4 lb.
Carbon in combustible	(9)	84.6 per cent
Hydrogen in combustible	(10)	15.4 per cent
Ratio of carbon to hydrogen	(11)	5.5

In commenting on these examples it may be stated that the ultimate analysis was not available; hence, the proportions of hydrogen and carbon could not be checked. However, using average values from handbooks, satisfactory agreement was obtained. The theoretic air by the new formulas was found to check well with that from the average ultimate analysis of the fuel.

A characteristic difference between the boiler furnace and the gasoline engine is shown by the excess-air items, 54.0 per cent excess in the furnace, and 9.5 per cent deficiency in the engine. The latter is properly indicated by a minus sign in formula (7).

The consistency check, based on the weight of the products of combustion, is satisfactorily met.

Example 1.—Air + fuel = 19.40 + 1.00 = 20.40
Dry gases + water = 20.00 + 0.40 = 20.40

Example 2.—Air + fuel = 13.65 + 1.00 = 14.65
Dry gases + water = 13.20 + 1.40 = 14.60

From these and many similar applications it has been fairly well proved that the formulas can be relied on for satisfactory results, provided that the gases have been carefully sampled and analyzed.

Appendix—Derivation of Formulas

These formulas are deduced under certain limitations which may be stated as follows: (*a*) hydrogen in the fuel is assumed to be negligible in amount; (*b*) sulphur in the fuel is also assumed to be negligible in amount; (*c*) hydrogen, as used in the formulas, refers to the free hydrogen, $H - (O/8)$, or the portion of the hydrogen that requires air for its combustion. It is further assumed that the combustion is fairly complete, so that no unburned fuel is found in the products of combustion, except small amounts of carbon monoxide. With these assumptions complied with, the gases can be analyzed by the Orsat apparatus, and the results can be interpreted by the formulas.

In the combustion process the carbon and the hydrogen of the fuel unite with the oxygen of the air, yielding products that may be designated as follows:

Carbon dioxide	CO_2
Carbon monoxide	CO
Water vapor	H_2O
Free oxygen	O_2
Nitrogen	N_2

The percentage volumes of four of these products are determined by the Orsat apparatus, while one, water vapor, escapes without measurement. It is convenient to denote the percentage volume by the symbol. Thus, N_2 denotes not only nitrogen, but refers to the percentage of it given by the analysis, whenever it is used in a formula.

The weight of the various products can be expressed in terms of the volume by means of the appropriate atomic weight numbers. Knowing the weight of oxygen or nitrogen, the weight of the air can be found by dividing the oxygen by 0.23, or by dividing the nitrogen by 0.77. The atomic-weight method fails in the case of hydrogen, because its product, water vapor, is not included in the exhaust analysis.

The weight of hydrogen in the fuel can be arrived at indirectly, by equating two expressions for the total weight of air. From the nitrogen,

$$\text{Weight of air} = 28\ N_2/0.77 \tag{12}$$

From the products CO_2, CO, H_2O, O_2,

$$\text{Weight of air} = \frac{32\ CO_2}{0.23} + \frac{16\ CO}{0.23} + \frac{8\ H_2}{0.23} + \frac{32\ O_2}{0.23} \tag{13}$$

Equating the two expressions and solving for hydrogen,

$$H_2 = 1.05\ N_2 - 4\ (CO_2 + O_2 + CO/2) \tag{14}$$

The following can be written directly from the atomic weights:

$$\text{Weight of carbon} = 12\ (CO_2 + CO) \tag{15}$$

$$\text{Weight of combustible} = 1.05\ N_2 + 10\ CO + 8\ CO_2 - 4\ O_2 \tag{16}$$

$$\text{Weight of dry gases} = 44\ CO_2 + 28\ CO + 32\ O_2 + 28\ N_2 \tag{17}$$

$$\text{Air theoretically required} = \frac{12\ (CO_2 + CO) \times 32}{12 \times 0.23} + \frac{8\ H_2}{0.23}$$

Inserting H_2 from (14),

$$\text{Weight of air theoretically required} = 36.5\ N_2 + 69.6\ CO - 139.2\ O_2 \tag{18}$$

The weight of water vapor is nine times the weight of hydrogen; hence,

$$\text{Weight of water vapor} = 9.45\ N_2 - 36\ (CO_2 + O_2 + CO/2) \tag{19}$$

The foregoing weights are all expressed in the same units; hence, they are comparable for derivation of formulas, as indicated below. In this list the numbers in parentheses between the signs of equality refer to the expressions in the body of the paper and the appendix.

$$\text{Weight of air per pound of carbon} = \frac{(12)}{(15)} = \frac{3.03\ N_2}{(CO_2 + CO)} \tag{1}$$

$$\text{Dry gas per pound of carbon} = \frac{(17)}{(15)} = \frac{11\ CO_2 + 8\ O_2 + 7\ (N_2 + CO)}{3\ (CO_2 + CO)} \tag{2}$$

$$\text{Ratio of the air actually used to the air theoretically required} = \frac{(12)}{(18)} = \frac{N_2}{N_2 - 3.78\ (O_2 - CO/2)} \tag{3}$$

$$\text{Weight of air per pound of combustible} = \frac{(13)}{(16)} = \frac{18.3\ N_2}{0.525\ N_2 - 5\ CO + 4\ CO_2 - 2\ O_2} \tag{4}$$

$$\text{Dry gas per pound of combustible} = \frac{(17)}{(16)} = \frac{22\ CO_2 + 16\ O_2 + 14\ (N_2 + CO)}{0.525\ N_2 + 5\ CO + 4\ CO_2 - 2\ O_2} \tag{5}$$

$$\text{Theoretical air requirements per pound of combustible} = \frac{(18)}{(16)} = \frac{18.3\ N_2 + 34.8\ CO - 69.6\ O_2}{0.525\ N_2 - 5\ CO + 4\ CO_2 - 2\ O_2} \tag{6}$$

Per cent of excess air =

$$\frac{(12)-(18)}{(18)} = \frac{69.6\ O_2 - 34.8\ CO}{18.3\ N_2 + 34.8\ CO - 69.6\ O_2} \quad (7)$$

Water vapor per pound of combustible =

$$\frac{(19)}{(16)} = \frac{4.77\ N_2 - 9\ CO - 18\ (CO_2 + O_2)}{0.525\ N_2 + 5\ CO + 4\ CO_2 - 2\ O_2} \quad (8)$$

Percentage of carbon in combustible =

$$\frac{(15)\times 100}{(16)} = \frac{6\ (CO_2 + CO)\times 100}{0.525\ N_2 + 5\ CO + 4\ CO_2 - 2\ O_2} \quad (9)$$

Percentage of hydrogen in combustible =

$$\frac{(14)\times 100}{(16)} = \left[\frac{0.525\ N_2 - CO - 2\ (CO_2 + O_2)}{0.525\ N_2 + 5\ CO + 4\ CO_2 - 2\ O_2}\right]\times 100 \quad (10)$$

Ratio of carbon to hydrogen in combustible =

$$\frac{(15)}{(14)} = \frac{6\ (CO_2 + CO)}{0.525\ N_2 - CO - 2\ (CO_2 + O_2)} \quad (11)$$

RURAL CREDITS

FARMING is a small-unit business. In 1920 the 6,448,343 farms of this Country contained an average per farm of 148.2 acres, and the average value per farm of all farm property, including land, buildings and implements, was $12,084. Although the capacity to withstand adversity is increased by this multiplicity of units relative to the aggregate output, some obvious advantages of large producing units, characteristic of so much of the Country's industrial production, are not shared in general by the farmers.

The Joint Commission of Agricultural Inquiry in its report to Congress in 1921, said:

> If we consider that the farmer could make 5 per cent on his total property by investing it elsewhere and that only the residue of his income is payment for his efforts, the following conclusions follow for the year 1913: Had the farmer gone to work as a farm laborer, his average labor income would have been $328, instead of $444. Had he worked instead in the mining industry at the average earnings of the employe in that industry, he would have received $755, or about 70 per cent more than his actual labor income. The farmer in 1918 had an income of $1,278 resulting from his labor, risks and management. Had he worked in the mining industry for the average earnings of the employes in that industry, he would have received a wage of $1,280 or almost exactly the amount of his actual earnings. Had he worked as an employe in the railroad or banking field, he would have made materially more for his labor than he did on the farm, but he would have been worse paid had he received the average earnings of those employed in factories, in public utilities, in Government or in unclassified industries.

The purpose of the United States Warehouse Act, which became a law in 1916, was to establish a form of warehouse receipt of cotton, grain, tobacco, wool and flaxseed that might make these receipts readily negotiable as delivery orders or as collateral for loans. Accordingly, acceptable warehousemen are licensed for the storage of these products. The rapid growth in the number of warehouses licensed under the Act is evidence of the need for the services which they are now rendering.

Information about conditions in the consuming markets is regularly accessible now but generally speaking the sellers of farm products that have world markets are not so well informed about consumption as are the buyers about production. It is the opinion not only of farmers, but of competent students of marketing problems, that in the distribution of farm products there is an excessive duplication of middlemen, with a tendency to depress unduly the prices paid the producers and to raise the costs to the consumers. Doubtless much can be done to eliminate unnecessary services in the distribution of farm products, and of other commodities as well.

The first practical effect of the discussion of rural credit problems in the period between the panic of 1907 and the outbreak of the World War, in the form of legislation to provide new credit facilities for farmers on a national scale, came with the passage of the Federal Reserve Act in 1913. The law made agricultural paper, that is, notes, drafts and bills of exchange, drawn or issued for agricultural purposes or based on live stock, with a maturity not exceeding 6 months, eligible for discount by Federal Reserve Banks. Other eligible paper was restricted to a maturity not exceeding 90 days. Thus, the law specifically recognized the difference between acceptable maturities for agricultural paper on the one hand and industrial and commercial paper on the other. The fact that most of the State banks have not become members of the Federal Reserve System, from choice or because of lack of qualification, has greatly restricted the proportion of the aggregate agricultural bank loans that may be discounted by Federal Reserve Banks. Moreover, the range of maturity of eligible agricultural paper is regarded in many quarters as too narrow.

Some light is thrown upon the question of the comparative amounts of credit extended to agricultural and to all other classes of borrowers by investigations for the Joint Commission of Agricultural Inquiry, which indicated that "in general the expansion in the agricultural States during the period of inflation was at least as great, if not greater, than in the industrial States." It was found also from a study of reports of about 9500 member banks that "between May 4, 1920 and April 28, 1921, the loans and discounts of banks in agricultural counties throughout the country declined $36,500,000, or slightly more than 1.2 per cent; the loans and discounts of banks in semi-agricultural counties declined $18,700,000, or 1.3 per cent; and the loans and discounts of banks in non-agricultural counties declined $827,100,000, or 5.6 per cent. The borrowings from the Federal Reserve Banks by banks in agricultural counties increased $127,600,000, or 56.6 per cent; borrowings by banks in semi-agricultural counties remained practically stationary; and borrowings by banks in non-agricultural counties declined $629,100,000, or 28.5 per cent."

The Federal Farm Loan Act of 1916 provided for the establishment of 12 regional Federal Land Banks. Loans running for not more than 40 years and not less than 5 years are made on the security of first mortgages on farm land through national farm-loan associations of 10 or more farmers each, or through specified agents. The maximum loan to an individual is $10,000, and the maximum interest that may be charged on loans is 6 per cent, but in no case is the rate to exceed by more than 1 per cent the rate paid on the last issue of bonds for raising the funds to be loaned.

The capital stock of the banks is owned by the Government, national farm-loan associations, borrowers through agents and individual subscribers. On Oct. 31, 1922, the Government's stock had been reduced to $4,264,880, of a total of $35,256,730. Nearly all of the remaining stock was owned by loan associations. At that time the net mortgage loans by the banks outstanding totaled in round numbers $606,000,000, and their farm-loan bonds authorized and issued amounted to $641,000,000. These bonds and the mortgages on which they are based, as well as the capital stock of the banks, are exempt from taxation.

Besides the Federal Land Banks, the Act permits the establishment of Joint-Stock Land Banks and authorizes them to lend directly to borrowers on farm mortgage security and to issue farm-loan bonds. The number of these banks, 61 in November, 1922, was more than doubled in the last year.

From Jan. 4, 1921, to Nov. 30, 1922, the War Finance Corporation had approved advances to banks, live-stock loan companies and cooperative marketing associations, for agricultural and live-stock purposes, in 37 States, amounting to $433,000,000.—*Guaranty Survey.*

1922 and the Motorboat Industry[1]

By H. H. Brautigam[2]

DURING the year just ended, great progress has been made in the motorboat industry in this Country. This statement applies with equal force to the commercial and the pleasure aspects of the industry. Marked developments in power, as well as an advance in construction, have made the past year a notable one. Briefly, the outstanding features seem to have been the greater development and a more widespread acceptance of the standardized boat, the production of high-power engines of the Diesel type for use on commercial vessels in place of steam, the noteworthy improvement in the design and the efficiency of the high-power, high-speed engine and the further perfection and development in the use of the outboard engine.

The outboard engine, when it first came into use some years ago, was little more than a toy designed for boys to place on a rowboat. But gradually it has been developed and made more and more reliable. With their greater reliability a rapidly increasing demand for engines of this kind has arisen. During the past year a number of new companies have entered the field, with the result that the outboard engine is used constantly on the tenders of yachts in place of man-rowing power.

While one or two builders have, by the use of aluminum, succeeded in making very light machines of this type, the question of light weight is not given so much consideration now that the demand is for a steady, reliable engine. Cylinder dimensions have been increased, which of course gives the engine more power and makes it more serviceable. There is also a tendency to make two-cylinder powerplants instead of the one-cylinder outboard engines that were first constructed. Both battery and magneto ignition are used. Besides being used on the tenders of yachts and Government boats, these little engines have proved a great boon to the rod and line fisherman. On Chesapeake Bay they are used almost exclusively in trolling for rock fish.

While the cost of fuel has exerted a tremendous influence in the building of engines for the medium-size and the large boats of both the pleasure and the commercial types, it has had little or no effect upon the production of the small, low-power gasoline engine used for small passenger and pleasure boats. On these smaller machines where the cost of fuel consumed is small, and therefore less of an item in the expense of operation, the demand has been for a better, cleaner and quieter engine. The high development of the four-cylinder four-cycle engine has met this demand. The extent to which this development has been carried by the builder can be seen readily by comparing the engines of this year's construction with those produced 5 or 6 years ago. Within the past 12 months great advances have been made in the production of automotive apparatus, in castings, crankshafts and the like, and the engine builder in many instances, by availing himself of these improvements, has been enabled to decrease his production costs to the ultimate benefit of the purchaser.

The past season witnessed the introduction to the yachting public of a number of high-speed marine engines with horsepowers ranging from 50 to 200 and more. These engines, masterpieces of design and construction, have already given a good account of themselves in every test to which they may have been put. Some of these engines were installed in high-speed runabouts and were subjected, during the various race-meets held in the past season throughout the Country, to a series of grueling tests. Others were installed in cruising boats of various sizes where sturdiness and reliability were vitally necessary. In every instance these engines performed fully up to and beyond the claims of their builders. Greater things are expected of these engines during the coming year, as the builders, with all of this experience behind them, have been ceaselessly experimenting and testing with the sole object in view of being able to offer to the public a high-speed engine of the first grade with unquestioned power and endurance as well as the greatest reliability.

The larger high-power engines of the Diesel type have in the past year been advanced considerably in efficiency and are gradually displacing steam in commercial vessels in which a great amount of power is required, such as tugboats, coasting barges, tankers and even transoceanic freight vessels of large tonnage. Around New York Harbor tugboats are being constantly equipped with these engines for harbor usage and for towing through the New York State Barge Canal. Recently they have been installed in all the tugs of the Transmarine Corporation. On the Great Lakes they are being used in grain-carrying hulls. On the Pacific Coast, where the tendency to use them in place of steam is even greater than on the Atlantic Coast, barges and freight vessels are constantly equipped with them. Their advantages are many and obvious. They have proved highly efficient and powerful. They cut down the cost of transportation by being more economical than steam in the man-power and fuel needed to run them. And their usage makes for a cleaner boat, for they do away with the stoker and the annoyance of continually emptying ashes. But one engineer is needed to run them in place of the engineer and two or three firemen needed with a steam engine. The fuel for these engines is easily obtained and the power plant itself requires less space than a steam engine, aside from the coal that must be carried with the latter.

Developments in Boat Construction

In boat construction the past year showed three outstanding features, the development of the luxurious type of houseboat, the improvement of the standardized cruiser and the wide acceptance of the V-bottom speed-boat. The houseboat, in the past nothing more than a flat-bottomed barge with a clumsy square house built upon it, has in recent years been changed into the power-houseboat. Many of these boats, especially the ones designed and built for the winter season in Florida and other Southern waters, are exceedingly comfortable, luxurious vessels. While they are built primarily for comfort, they are also very able vessels. Many of them have very good speed, making from 9 to 14 m.p.h. With

[1] Annual report of the Second Vice President representing marine engineering.

[2] M.S.A.E.—President, Bridgeport Motor Co., Bridgeport, Conn.

these boats the clumsiness of the old-fashioned houseboat has been entirely eliminated. They are now designed with no little thought of appearance, show very good lines and are often just as graceful as the yachts surrounding them. Such houseboats are capable of cruises from our coasts to the beautiful islands of the West Indies where many of them can now be found every winter. In fact, in this Country, it has become the custom to start from the Great Lakes or the North Atlantic coast in one of these cruising houseboats about the first of November, travel down the coast to Florida, Cuba, Jamaica or the Virgin Islands and spend the winter months in the warmer waters. To just what extent prohibition in the United States has tended to develop this custom would be hard to estimate.

The interior fittings of these houseboats have become really magnificent. The craft are equipped with every imaginable device that could possibly add to the comfort of the owner and his guests. Immense saloons on the main deck serve the purpose of not only lounging rooms, but in many cases this part of the houseboat is equipped with pianos, and sometimes large electrically operated organs, and the saloon, with its smoothly polished floor, is readily convertible into a ballroom. Either a complete wireless outfit or at least a small receiving radio-set is found on practically all of these boats. Bathrooms are often tiled and fitted with both hot and cold showers. Galleys contain iceboxes of no mean dimensions and are often equipped with the latest electrical cooking devices. Lighting is almost invariably by electricity and steam or electric heating, a decided comfort on a chilly morning, is used. Bedrooms, living rooms and other quarters are often finished in mahogany and furnished with exquisite taste. In fact, many of these boats are so luxurious that living in them is as easy as living at one of our best hotels.

The standardized cruiser that made its appearance in greater numbers last year is a successful attempt to meet the demand for boats from people of moderate means. Many companies are now building such stock boats. Some of them are as small as 25 ft. in length, while others run up to 65 ft. An average size seems to be between 30 and 40 ft. overall by 8 to 10 ft. beam. Several builders are now putting out such a stock boat for from $3,000 to $5,000. These boats have well-built cabins and are equipped with every convenience required for an extended cruise. Boats of this type have shown great development within the past year. They have gradually been given more freeboard, so as to sit higher out of the water until now they are very able and seaworthy boats.

Boats of this type are always well powered with fully equipped engines. Most of the engines have electric starters and generators for developing current for the electric systems. Such cruisers are all one-man-controlled boats, the engine being started and controlled by the man at the steering-wheel. Their interiors generally consist of the cabins, bath, kitchen and engine-room. For small families or parties of three or four the standardized cruiser is an ideal boat, and one that is well within the means of the average boat enthusiast. Many of these cruisers will be seen this winter in Florida waters, a large number of them having traveled from our Great Lakes section by way of the Erie Canal, the Hudson River and the inland route along the Atlantic Coast. In Europe they would make excellent boats for cruising around Southern Italy, Sicily and the Mediterranean.

Where speed is a consideration the V-bottom boat is becoming more and more popular. In the races of the past year it repeatedly demonstrated how well deserved is this popularity. Not only does such a boat show more speed than the round-bottom type but it is much simpler in construction.

One or two other features of the industry deserve mention. There are, for instance, the rapid development of the auxiliary sailing boat, and the increasing popularity of the express runabout, a small open boat of perhaps 30 to 35 ft. that is capable of speeds up to 50 m.p.h. These runabouts are equipped with high-speed engines of from 50 to 200 hp. They can be handled readily by one man and are gradually being developed for fast messenger service.

In general, the tendency today is to meet the demand for a less expensive boat, at no sacrifice of speed, comfort or efficiency, by the use of standardized parts in the engine and the production of a standardized boat. In fact, the price of a boat of good construction is down to a figure that is well within the reach of the average man. In this Country today the statement, "a boat for everybody," can be applied much more truthfully to motorboats than a corresponding statement can be applied to automobiles. A complete motorboat of the small open type, equipped with a serviceable engine, can be bought new at present for less than $300, a figure considerably lower than the price of even the cheapest automobile on the market.

Cyrus H. K. Curtis, owner and publisher of the *Saturday Evening Post*, spends the greater part of his time aboard his wonder yacht Lyndonia. In an interview just recently at Miami, Fla., where the Lydonia is now stationed, Mr. Curtis said:

> Yachting pays in a score of ways. They say you cannot have your youth back, once you have passed the milestone of maturity and age. I disagree with that. I have had my youth back and still have it. The sea knows no age, and those who live on it partake in time of the same quality of strength and restful motion that is part of the ocean. I have never felt better in my life than I do today. I know it is the yacht that is doing this for me. Life seems happier on this deck, problems simpler and a cigar tastes better.

A NEW TYPE OF RAIL-CAR

In connection with the discussion on rail-cars, reported in THE JOURNAL for December, 1922, attention is drawn to the detailed description in *The Engineer* for Dec. 29, 1922, of the European Diesel-electric car mentioned in Roy V. Wright's paper. This rail-car has an overall length of 70 ft., and weighs, empty, 65.52 tons; it has a seating capacity of 69. The powerplant is a six-cylinder, four-stroke Diesel engine developing 200 hp. at 440 r.p.m., running on tar-oil injected directly into the cylinders without the use of air. The returns for a full month's working in branch-line service conditions on a 46-mile section show an average fuel-consumption of 0.043 lb. per ton-mile, including the fuel used when the car is engaged in switching service, providing compressed-air for the airbrake system and recharging the storage-batteries.

The trial runs made on a branch line of the Swiss Federal Railroad system are reported as having been satisfactory in every respect, and it is anticipated that this rail-car will show a considerable saving as against the running costs of the ordinary electric train.

Stationary Internal-Combustion Engineering Developments[1]

By C. B. Segner[2]

THE name Stationary Internal Combustion Engineering, as applied to the work of a group in the Society, is somewhat anomalous, as most of our members intended to be included in this classification are interested principally in the small general-purpose portable and semi-portable engines used for driving farm machinery, concrete-mixers, gasoline hoists, pumps, and apparatus of similar nature. The "real" stationary engines are those used for driving factory apparatus, electric generators, rolling-mills, and other heavy machinery. They form the basis of a very important industry and their design and construction should be of interest to all our members, but the activities of the group of the Society of which I have been vice-president, seem to have been confined very largely to the smaller types of engine mentioned.

The general-purpose engines have been developed to a wonderful degree of simplicity, and American methods of production have brought their cost very low. The majority of them are of the single-cylinder medium-speed type, using magneto ignition and being supplied with a throttling governor and with a carbureter or mixing-valve that permits the use of either kerosene or gasoline as a fuel. Developments of this class of engine are progressing along several different lines. Existing models are being made more reliable by the use of better magnetos, carbureters, and lubricators.

Some of the work formerly handled by the general-purpose engine is now being done by special engines designed for specific purposes. Among these are the engine for the isolated electric lighting-plant, the little engine used for driving the knotting mechanism on grain binders, and the farm pump engine. I believe, however, that the most important trend of development is the use of multiple-cylinder automobile or tractor type engines, especially in the larger sizes, above 6 or 8 hp. These engines are sold as complete power units with all accessories, such as magneto, carbureter, governor, fuel-tank and power takeoff, all enclosed in a metal housing. These light, convenient and reliable powerplants are coming more and more into favor, especially for driving pumps and hoists, and for industrial work that demands mechanical reliability.

The single-cylinder general-purpose engine, because of its low cost and simplicity, will without doubt be built and sold in large quantities for many years but, if I may venture a prediction, I would say that the principal developments will be in the direction of special engines for specific purposes and of units for industrial purposes. In this event the engines will become more nearly like the automobile and tractor engines in design and equipment. This constitutes another argument why all engineers and production men engaged in the "stationary internal-combustion engineering" industry should be members of the Society of Automotive Engineers, in which are available the benefits of the experience gained in the development of automobile and of aircraft engineering, as well as of the S.A.E. Standards for materials and dimensions of various component parts and accessories of engines.

[1] Annual report of the Second Vice-President representing stationary internal-combustion engineering.

[2] M.S.A.E. Vice-President and general manager, Domestic Engine & Pump Co., Shippensburg, Pa.

OBITUARIES

Albert H. Miller, research engineer for the Nicetown Works of the Midvale Steel & Ordnance Co., Philadelphia, died at his home in that city on Jan. 11, 1923, aged 42 years. He was born on Aug. 27, 1880, at Philadelphia, and following his public school education matriculated at the University of Pennsylvania in 1897, being graduated in 1901 with the degree of Bachelor of Science in mechanical engineering. In 1908 he took a special course in heat-treatment and the structure of steels at the Sorbonne, in Paris, France.

Mr. Miller made a life study of the scientific features of steel manufacture. He was particularly skillful in analyzing steels microscopically, and in designating appropriate heat-treatments to secure the desired physical properties. At the time of his death he was in charge of the development of new products.

He was a member of the American Society for Steel Treating, and at times read papers upon metallurgical subjects, his latest being one on the Commercial Heat-Treatment for Structural Steels, read before the Washington section of the American Society of Mechanical Engineers. He was also a member of the Philadelphia Engineer's Club and of other fraternal and social organizations. He was elected to Member grade in the Society on March 7, 1922.

Alfred Thomas Sturt, chief engineer of Durant Motors, Inc., Long Island City, N. Y., died of scarlet fever on Jan. 23, 1923, aged 44 years. He was born at Flint, Mich., in 1878 and received his scholastic education in the Flint high school. Entering the service of the Buick Motor Co. in 1903, he served it progressively until 1912, when he became assistant engineer for the Dort Motor Car Co. In 1913 and 1914 he was chief engineer for the Mason Motor Co. and also chief engineer of the Chevrolet Motor Co. in 1915, later forming a connection with Durant Motors at the time of its organization. He was elected to Member grade in the Society on Feb. 16, 1916.

SOCIETY MEETINGS

SHOP AND ENGINEER MUST COOPERATE

Detroiters Say Team-Work Is Essential in Successful Manufacturing Organization

The promotion of a better understanding between the factory-man and the engineer is a theme rather worn with discussion, but it served as the topic of a lively and successful meeting of the Detroit Section on Feb. 2. Incidentally, any effort made toward accomplishing the ideal of arm-in-arm team-work between the designer and the producer is akin to the times; there has never been such a decided tendency in this direction since the creation of the first motor-car as there is at the present time.

L. V. Cram, production engineer with the Chevrolet Motor Co., read a paper in which he stressed the value of a more intimate contact between the engineering and the manufacturing departments. He argued that engineering service must not be considered complete when it provides satisfactory drawings, bill-of-material and an efficient alteration system. There is a fourth requisite equally important, the presence of an engineer of judgment in the shop all the time, keeping pace with production development, making decisions, giving courteous advice and seeing that proper record is made of all improvements in method or product that originate in the shop. No producing organization stands still for a minute; ideas are germinating all the time in the interest of progress and many of these are worthy of adoption. It is the function of the engineering department to seek these out, pass judgment on them and effect their application. This necessitates the engineer's presence in the shop. It is a mistake to take a mechanic from his machine into a private office in the hope of securing his ideas; the change in environment makes him self-conscious and, usually, silent. Cultivate the spirit of cooperation in the shop, encourage the submission of suggested improvements, and the constantly improving product will reflect credit on the engineer eventually.

George E. Goddard read a paper prepared by H. W. Hayes in which the method of effecting alterations in the Dodge Bros. factory was explained. It was of particular interest to learn that a small number of altered parts or units were run through the complete manufacturing and assembly routine before an alteration was made effective definitely. This procedure assures the clearing up of many unanticipated interferences and objections before the alteration takes final form, thus eliminating disagreeable production tie-ups when the change becomes effective.

Organization Likened to Football Team

Walter Fishleigh, of the Ford Motor Co., gave an inspiring and forceful talk on the oft-ridiculed philosophy of cooperation. He stated that the factories which seem to accomplish the greatest success are often those with the most meager and undeveloped system and organization. It was his belief that most executives underestimate the importance of morale and teamwork in the proper functioning of an organization. System and organization rules were likened to the signals of a football team; they are an important accessory, but without team-play are ineffective. Mr. Fishleigh is of the opinion that all engineers are production men in this sense. Engineering "departments," considered as units set apart and separated from the shop by frosted glass partitions, should not exist. Engineers must come from behind these partitions, interest themselves in the shop and get acquainted with its men. This is fundamental to teamwork and true organization. Too many partitions are directly responsible for the feeling in some production departments that cars must be built "in spite of the engineers."

The words "change" and "alteration" should be discouraged; substitute in their stead the term "improvement." Mr. Fishleigh remarked that any change which is not an improvement lacks justification. No successful product endures without constant improvement and this of necessity means constant alterations.

K. L. Herrmann, O. E. Hunt, T. J. Litle, Jr., and others participated in the discussion following the papers.

Painting, the Topic of March Meeting

L. V. Pulsifer, chief chemist, Valentine & Co., will address the Detroit Section at its meeting on Friday, March 2. His topic will be "Painting Practice and Problems from the Chemist's Viewpoint." The meeting will be held in the General Motors Building, starting at 8 o'clock and will be preceded by an informal dinner at 6:30 p. m.

DAYTON HAS INTERESTING MEETING

Members Hear Talks on Alloy-Steel Valves and Wire, Steel and Wood Wheels

The Dayton Section tried a new feature as a part of its meeting program on Feb. 20, and it met with considerable approval. Immediately following the dinner, informal talks were given on the relative merits of various forms of automotive wheels. Louis H. Rogge championed the wire and metal-spoke wheel, F. H. Walkley supported the cast-steel wheel, and Mr. Weisner spoke for the wood-spoke and wood-disc wheel.

Glenn A. Toaz read an informative paper on valve problems encountered in the automotive engine. His talk included historical sketches of different types of valve that have been used in internal-combustion engines and discussion of their limitations. He traced the development from the cast-iron valve up to the recent silchrome alloy-steel type. Slides were shown illustrating the condition of the different valves and valve steels after a life-test in engines and after oxidation tests in furnaces.

RIVER BOATS USE OIL ENGINES

Engineer Describes New Tow-Boats Developed for Freight Traffic on Mississippi

Two of the newer applications of the internal-combustion engine were considered at the meeting of the Minneapolis Section on Feb. 7. Papers were read on the Mississippi River tow-boat and the motor rail-car. The former paper was read by J. Brodie, engineer of the River Transit Co., St. Paul, Minn. He said that the following matters must be considered in the design of freight-carrying boats due to Mississippi River channel conditions: first, the maneuvering ability of the stern-wheel steamboat of the old type is primarily essential for moving any kind of load on the river; second, adequate protection must be given the cargo in all kinds of weather; third, cheap and dependable methods must be devised for the handling of freight at the terminal; and fourth, boats must be operated with such frequency that sailing dates will be close enough to make the service attractive in the way of early delivery for shippers. Mr. Brodie felt that the fleet of tow-boats built by the Government at an expense of $3,500,000 was not entirely practical since the channel is too narrow and too crooked to steer long tows through without getting them stuck. These Government barges have a capac-

ity of about 1600 tons each and the tow-boats, equipped with 2000-hp. engines are capable of moving three or four barges at a time.

Mr. Brodie discouraged the old practice of handling passengers and freight on the same boat; the two types of traffic cannot be handled together profitably because of the frequent stops necessitated by the freight service with uncontrollable delay at each stop. He believed that the increased use of motor trucks and the extension of good roads are discouraging to short water-hauls but advantageous to long water-hauls.

For the present at least, Mr. Brodie recommends that river freight barges be about 300 ft. long and 80 to 100 ft. wide, with a draft not exceeding 3 ft. The size of these boats could be increased with the development of traffic, but if the most efficient craft is put on the river at the start, the amount of freight that the carrier can get will not be sufficient to secure maximum efficiency from the craft. There is some question whether a self-propelled boat or a tow-boat with barges is more practical. The barge system is more flexible since barges can be left at docks for loading or unloading and the tow-boat itself can be kept in operation continually. With the barge system, a single crew, specialized in the moving of barges with an efficient tow-boat, can move considerably more freight than with any other method. This is due largely to the fact that one specialized crew handles operation and another the loading and unloading of the barges. The self-propelled boat has the advantage of being able to move anywhere as soon as its load is removed; sailings will be more frequent and this feature alone is sufficient in some cases to demand the use of the self-propelled boat. Its greatest disadvantage is that the navigating crew and engines are idle while the boat it at the dock.

With the stern-wheel tow-boat, the slow motion of the paddle-wheel makes the application of the direct-connected steam-engine by far the most simple mechanism. The weight of the boiler, engines and fuel in such a boat is a great disadvantage; in addition, fueling with coal ties-up the equipment too long a time. The small amount of power required on each unit makes the oil-burning internal-combustion engine readily adaptable. The possibility of one man operating both the steering mechanism and the engine is another feature favoring the automotive engine. The transmission of power is the big problem when utilizing the internal-combustion engine. This is largely due to the fact that the use of propellers in tunnels in the hull of the boat has not proved entirely satisfactory. One of the necessities in tow-boat operation is ability to back with a strong sidewise force and this quality is not pronounced in the tunnel-propeller boats. It is generally agreed that there is no means of propulsion as effective in steering and stopping as the stern wheel with rudders both in front of and behind it. Mr. Brodie's organization is planning to use a tractor transmission between the engine and the paddle-wheel, throwing the engine out of engagement and applying brakes to the paddle-wheel until it is stopped; the clutch can then be engaged for driving in the reverse direction. He intends to use a 75-hp. engine that will be capable of driving the boat at a speed of 8 m.p.h. in still water. This speed is about as great as can be obtained efficiently during the low-water periods on the Mississippi River and Mr. Brodie considers any additional power would be wasted.

The paper on motor rail-cars was read by E. Russell Greer, engineer of the Service Transfer Co., St. Paul, Minn. This paper was principally a resume of the material already published on the motor rail-car and included a description of the car designed by C. O. Guernsey and operated by the Great Northern Railway. This particular car is mounted on two trucks each having four wheels; the wheels have rubber cushions mounted between the steel rim and the flanges to absorb shocks. All four wheels of the front truck are positively driven by a four-cylinder engine developing 66 hp. The car seats 44 persons and is provided with baggage space; it runs 200 miles a day and is operated by a crew of two men. It was interesting to note that the car does not carry the standard railroad couplers which weigh 400 to 500 lb. apiece. A standard railroad airbrake system is used, the compressor being driven by the engine. The engine installation is arranged so that the entire powerplant can be removed from the car for overhauling and replaced with a new unit without tying-up the entire equipment.

The next meeting of the Minneapolis Section is scheduled for the evening of March 7, when Charles Boehnlein of the University of Minnesota faculty will outline the Development of the Modern Airplane. The meeting starts at 8 o'clock in the Builders' Exchange headquarters.

NEW HEAD-LAMP ILLUMINATION CHART

A new method of graphic representation of head-lamp illumination will be presented as part of a paper on Road Lighting to be read by F. H. Ford at the Mid-West Section meeting on the evening of March 23. Mr. Ford has experienced difficulty in presenting comparative data on non-glare lens effectiveness to engineers who have never used photometric charts. He has developed a new chart that presents these data in a simplified form showing clearly the variations in light intensity. Other interesting material on lenses, reflectors and road-illumination will be a part of the paper. The meeting will be held in the rooms of the Western Society of Engineers, Monadnock Building, starting at 8 o'clock.

TRUCK OPERATION TO BE FEATURED

Society Meeting at Cleveland in April Appeals to Operators and Manufacturers

The Meetings Committee has set the dates of April 26 to 28 for the National Meeting on Automotive Transportation. The Hotel Winton has been selected as headquarters for the meeting. It is centrally located and has a large garage adjacent to it where members driving to the meeting can store their cars.

Several papers have been definitely secured by the Committee for presentation at the Meeting. F. C. Horner, motor transport engineer with the General Motors Corporation, will describe some of the successful methods of operation being practiced in large European cities. This paper will be accompanied by numerous stereopticon illustrations and motion pictures. Types of bodies, loading and unloading equipment, and methods of routing and dispatching will be described by him. A second paper on motor-truck operation is being written by S. G. Thompson, chief transportation engineer of the White Motor Co., in collaboration with A. J. Scaife. This paper will describe methods of controlling the operation of a fleet of motor vehicles and include the practices of some of the most successful motor-transport organizations.

Major Brainerd Taylor, of the Motor Transport Corps of the Army, will read a paper describing an emergency system of motor-truck transportation that the Army was prepared to set up and operate in case of failure of the national transportation system during the railroad strike of 1922. This paper includes much of the experience of the Army transport officers resulting from the stupendous task of carrying on the truck transportation of the Service of Supply in France during the War. S. Von Ammon, of the Bureau of Standards at the City of Washington, will read a paper on the motor-truck axle tests that have been conducted by the Bureau. These tests have resulted in the gathering of extremely valuable data on the efficiency of motor-truck axles. Prof. W. E. Lay, of the University of Michigan, will contribute a paper describing some of the motor-truck testing work that has been done by the University staff to determine the gradient of highways that will be conducive to maximum economy of vehicle and road when the two are considered jointly.

Several other valuable papers are being considered for the program of this Automotive Transportation Meeting. It is evident that the sessions will contain much valuable material for both the constructor and the operator of trucks. It is expected that many motor-truck operators will attend

the meeting, particularly railroad representatives. Watch your future issues of the *Meetings Bulletin* for further details of the program. In the meantime, make arrangements to be in Cleveland on April 26 to 28.

SPRING LAKE SUMMER MEETING SITE

Jersey Coast Resort Selected Because of Its Unusually Attractive Features

The Summer Meeting of 1923 will be held at Spring Lake, N. J., June 19 to 23. This announcement was made by Mason P. Rumney, chairman of the Meetings Committee, at the Chicago Dinner and in a recent issue of the *Meetings Bulletin*. The selection was made after a careful canvass of all other available resorts in the East and Middle West. To those who strongly recommended a return to White Sulphur Springs it should be stated that the West Virginia resort could not accommodate us this year because its building program involves the razing of the White, thus limiting attendance to the capacity of the Greenbrier. The Committee feels that Spring Lake possesses the meeting and sport facilities of White Sulphur Springs, with the added attractions that are a part of a great seashore resort.

Spring Lake is situated on the Atlantic Coast between the better-known Atlantic City and Asbury Park. It has all of the climatic and geographical advantages of these two resorts without the congestion and bustle. The Hotel Monmouth and the Essex and Sussex are comparable with the finest resort hotels along the coast; a majority of the rooms have private bath. Spring Lake is easily accessible by rail through the New York City and Philadelphia terminals, being only two hours from these cities. The Society has secured reduced-fare concessions from the railroads from nearly all points in the automotive districts east of Chicago. Recreational facilities at Spring Lake include two 18-hole golf courses, numerous tennis-courts, baseball field, ocean bathing, swimming-pool, trapshooting and saddle horses. The climate in June is moderate.

Special issues of the *Meetings Bulletin* will reach the entire membership in advance of the Summer Meeting and to these will be left the task of giving in picture and printed word all of the attractive features of Spring Lake, and the important engineering and business sessions that will be arranged as a part of the Summer Meeting.

BUFFALO SECTION MARCH MEETING

J. Edward Schipper, technical writer, will address the meeting of the Buffalo Section on the evening of March 16. He will present a study of the trend in passenger-car development as exemplified by the New York City and Chicago Show exhibits. The meeting will be held at the Buffalo Engineers' Club in the Iroquois Hotel, starting at 8 o'clock.

GOVERNING FACTORS IN AUTOMOBILE SERVICE

Inspiring Papers and Discussion at Chicago Service Meeting

It is obvious that the prestige and lasting success of automotive companies, particularly those engaged in the passenger-car and motor-truck fields, depend upon the satisfaction their products render. Service is an integral part of their activities that cannot be long ignored. To maintain position in the highly reputable and prosperous way that it should be maintained, and will be maintained by those who shall survive through coming years, motor-vehicle builders and dealers must meet in a fair and square manner their responsibilities which are inextricably linked with the needs of their car-using customers. One of the first thoroughgoing reductions to practice in scientific and engineering progress should be in the maintenance of the millions of motor cars now in operation, not to speak of the many millions more to come. The longer the comprehensive solving of this service problem is deferred, the more arduous it will be to accomplish. The establishing as fully as possible of desirable conditions in the very complex and widely scattered field of automobile service requires long and thorough study by the best brains of the industry.

The Technical Sessions

At the Service Meeting of the Society held in Chicago on Jan. 31, much definite information was given and many pertinent data submitted in this connection by well qualified men who presented papers and took part in the discussion. Don T. Hastings, who is vice-president in charge of service for Hupmobiles in Detroit territory, described in a clear manner the system that he and his associates have established, and related convincingly his views on the so-called flat-rate method of conducting a service-station. J. F. Page, general manager of service of the Packard Motor Car Co. in Chicago, suggested various things that he felt a motor-car builder should do in the way of cooperating with dealers. O. C. Funderburk, who is a distributor of Lincoln and of Ford cars in Boston, prepared for the meeting a paper outlining the fundamental considerations according to which he believes a service-station should be organized, and narrated in considerable detail salient features of the maintenance service which he has been instrumental in providing for the cars mentioned. A. H. Packer, of the *Motor Age* staff, described graphically the many essentially important benefits to be had through suitable standardization of electrical equipment such as generators and motors of automobiles, with special reference to maintenance. The papers presented by Mr. Hastings and by Mr. Page were included in the February issue of The Journal. Mr. Funderburk's paper, as well as that of Mr. Packer, is included in this issue.

The Flat-Rate System

Mr. Hastings said that the men working in his shop under the flat-rate system earn about 25 per cent more than they would earn if employed by the day or according to the customary hour-rate. He believed that perhaps the chief merit

COMING NATIONAL MEETINGS

AUTOMOTIVE TRANSPORTATION MEETING
Cleveland—April 26-28

SUMMER MEETING
Spring Lake, N. J.—June 19-23

PRODUCTION MEETING
Cleveland—Oct. 25-26

ANNUAL DINNER
New York City—January, 1924

ANNUAL MEETING
Detroit—January, 1924

of the flat-rate system is its appeal to the car-owner in that he knows what a given job will cost him before work on it is started; the rates being low enough so that there is no adverse criticism of the amounts charged. The customer is informed in advance of what the charge for new parts and material will be, if it can be foretold to what extent these will be necessary in the handling of the job. In reply to the view that was expressed at the meeting that the flat-rate system cannot be entirely fair to all car-owners, Mr. Hastings said that the time necessary to take on jobs does not vary 25 per cent in amount from minimum and maximum times except in extreme cases and that the general result is that, whereas one customer will not always gain as much as another in the reduction of a charge, all of the customers gain in this respect owing to the general speeding-up of the work going through the shop. He asserted that fairness is the fundamental basis of all service that is good. The customer at his option concurs as to the fairness of a charge before the work is started. Mr. Hastings was of the opinion that a car-user would in the long run pay more for repair work if he had it done on the basis of time-unit charging. Secretary Cobleigh, of the Service Committee of the National Automobile Chamber of Commerce, said that the average cost of repairs is always lower in the flat-rate system than in the observance of the older basis. He felt that even the careless car-owner gets his maintenance work done at a lower price when the flat-rate method of charging for service is followed.

Scope and Magnitude of Maintenance

Clyde Jennings, editor of *Motor Age*, presided at the afternoon session of the meeting. He pointed out that maintenance, which term he prefers to service in connection with the matters under discussion, is a larger field of endeavor than direct automobile production, from the standpoint of the number of people concerned and also with regard to the amount of money involved in the annual turnover. About $2,000,000,000 worth of new cars was sold at retail during the year 1922. The expenditure relating to maintenance, purchase of parts and labor was about $5,000,000,000 during the same period. He stated emphatically that the big thing before the automotive industry is service, this being a growing business. Many automotive engineers are devoting their entire time to service problems, working out some of the almost unlimited details involved. He said that the flat-rate system is of great value in "selling" maintenance, which must be made an easily understandable as well as properly conducted thing.

Mr. Funderburk, in his paper on the servicing of Lincoln and Ford cars, gave detailed information with regard to various tools that had been devised for the maintenance equipment. The members who reside near or shall have occasion to visit Boston are advised to call upon Mr. Funderburk, as he has generously expressed a willingness to show them through the shops of his company. Mr. Hastings also will welcome any of the members who wish to inspect his service-plant in Detroit.

J. W. Lord, service manager for Pierce-Arrow cars in New York City, felt that it would be better for the vehicle distributors to provide maintenance of electrical equipment themselves instead of having their customers depend for this upon the different manufacturers of the electrical equipment furnished on their cars.

The discussion at the two technical sessions of the meeting was very interesting and distinctly valuable. There was a keen appreciation of the necessity for further study and discussion of the vital principles at issue in the conduct of satisfactory service. The time to take intelligent action is in advance of the coming of obstacles that may be nearly insurmountable, and there is good prospect that those engaged in the design, production and servicing of automotive vehicles will do more and better work on the many great problems of car maintenance before the industry. As indicated herein, several excellent texts were presented at the Chicago Service Meeting. It is earnestly recommended that the members give close attention to them.

The dinner held at the Congress Hotel on the evening of Jan. 31 was a decidedly enjoyable and inspiring occasion. Major Godfrey H. Atkin did the toastmastering in a very acceptable manner. Edward S. Jordan, president of the Jordan Motor Car Co., was the principal speaker of the evening.

Address by Edward S. Jordan

The members were very deeply interested in what Mr. Jordan had to say in speaking to the subject, The Greatest Business in the World.

Mr. Jordan said that to secure accurate information on the idiosyncrasies of various prominent members of the Society he had visited the geographical center of the automobile industry, namely, the barber-shop of the Detroit Athletic Club; the said geographical center having been formerly the bar of the Hotel Pontchartrain in Detroit. After paying his compliments to the various colonels associated with the Society, he expressed the opinion that nevertheless the industry is as sound as a nut.

The speaker presented the view that, judging from the current volume of production, a total of 3,000,000 new automobiles will be made in this country this year. He pointed to the fact that if 2,500,000 automobiles are built this year it is reasonable to suppose that in addition at least 1,000,000 used cars will have to be sold during the same period.

Mr. Jordan made it clear that the fundamental thing behind success in those things on which transportation is based, is service. Essentials of the automobile business are men, money, good merchandise and a market. Of these, men are the most important, and they must have the spirit to serve well; a knowledge of the business; and know what they are doing, where they are going, and what they are trying to accomplish. They must recognize what service means, have courage to stop watching the man across the street and to analyze their own business and possess basic honesty.

In the course of his address, Mr. Jordan reiterated what he said at a meeting of the Detroit Section of the Society some months ago, namely, that the determining factor in the automobile business is not original list-price but the second-hand price; stating that millions of car-owners would take delivery of new automobiles promptly if the dealers in their localities could allow them what they consider enough for their present machines. That is the limiting factor of the business. The production end of the industry has been developed fairly well, and the factory capacity is considerably beyond that needed to meet the current demand for cars. The merchandising stage has been reached, and we are approaching the fundamental, vital stage, that of service. Mr. Jordan continued:

> When a man gets tired of walking, and of riding a bicycle or a motorcycle or in a street-car, he buys a Ford. It is a matter of social progress from that time. After he buys a Ford he saves some money, stays home nights and is under the influence of his wife. Then he gets a Dodge. He still is making social progress. Later, some Sunday morning, his wife notices a neighbor with a car that is always coming along with the cut-out open; this cut-out says, "I am coming socially." It is the Buick coming up the hill. As the Buick passes over the hill she decides that she ought to have a car in that field. They have arrived at the deadline of big-volume production, with the possible exception of the Cadillac.
>
> Leaving the Buick, we reach what we call the kissable buyers. The daughter comes home from college and the five family factors begin to operate: Father, who thinks in terms of economy; mother, who thinks of her children's opportunity; the daughter, who thinks of social prestige and a happy marriage; the boy who thinks travel, speed and pep. Then, there is a pet in every family; a horse, a dog, an automobile, a bank account, or a victrola or some other pride-possession. We have got to sell them on the possession of an automobile and what it can do for them.
>
> Those four human factors can function only through

their five senses; sight, which is color, the daughter wants the house painted a different color when she gets home from college; feeling, she wants a steam-heating system; taste, she wants a cook in the kitchen; atmosphere, she wants a rug and a picture; and hearing, she wants a victrola, and she doesn't want any noise in the transmission.

THE SECRET OF SUCCESS

I will tell you what I believe is the secret of success in any business. If you have an engineer who has brains and common sense and does not think he is a better engineer than ever lived before on the face of the earth, he will just try day after day, not to revolutionize the industry, but to take what men of intelligence have done before and build on that, and keep on improving and improving and gradually raising his curve of effectiveness; if your purchasing agent has brains enough and is well supported, he will go on buying with the idea of improving the service rendered by the product for which he is buying materials, and his curve naturally rises; and it follows naturally that the production curve rises, the selling curve rises, the cost curve goes down, the cost-of-service curve goes down, the profit curve gradually rises and there is more money coming into the accounting department than is going out, and you are a success in business, and get an invitation to address the Society of Automotive Engineers. There is nothing magical about it. It is just a matter of deciding each day what you know to be right, rejecting what you know to be wrong.

How are we to find out what to do in our business? There is only one way. If you are an engineer, do not ask the sales manager. He doesn't know; he thinks he knows. Don't ask the production man. Don't ask the fellow across the street. Ask the fellow we are all working for, the owner of the automobile. He will tell you all about what to do to your automobile; he knows all about it. If you see enough of him and get in touch with him, you do not need to know what the sales manager thinks because you know what the man wants.

One question that is very often asked is, Who will survive? It does not make any difference to me how many companies there are in the business today. It does not make any difference to me how many cars they built last year. The question is, What kind of service have they built into their automobiles? How much will they be worth 1, 2 and 3 years from now? Those who serve best will survive. If you are engineering honestly, purchasing intelligently, producing carefully, inspecting right, rendering the greatest possible service, selling according to a definite policy and never changing, not being guided by the man across the street, not simply trying to out-produce or out-sell or out-engineer some fellow around the corner, but going on day after day building a little better, pricing your product as best you can, from the standpoint of your facilities and overhead expense and rendering a higher degree of service day by day, trying honestly and intelligently to render more service and deliver a better dollar's worth of transportation to the man who drives your automobile, that is the best you can do, and that will keep you in the automobile industry. There are only a few experts in any line of business. There are only a few good salesmen. But I can tell any young fellow in this Country how to make a success in selling automobiles or anything else. The first thing he has to do, whether he is an engineer, a purchasing agent or a production man, is to make every man around him feel that he is sincerely trying to render a service to somebody else. Once he makes up his mind that he will do that; sets out definitely to do it, keeping in mind the other fellow and the service that he is rendering to him; and puts his heart and his soul into it, you just can't stop him.

SKIRMISH OF DESIGNERS AND SERVICE-MEN

Inaugural Joint Meeting of Metropolitan Section and Service Association

E. J. Rabidoux, president of the Automotive Service Association of New York, and W. E. Kemp, chairman of the Metropolitan Section of the Society, were umpires at the joint meeting of the two organizations held at the Automobile Club of America last month. Lee Eastman, president of the Packard Motor Car Co. of New York, and of the Automobile Merchants' Association of New York, was referee. The session, which was largely attended by service managers of automobile distributors doing business in metropolitan territory, was devoted to service-station problems. It was the first meeting of the kind that has been held and constituted an excellent beginning of more intimate contact between and increased effectiveness of designers of motor vehicles and service-men. Throughout the discussion there was a marked tendency to distinguish between engineers and service-men with regard to their technical qualifications. It is a fact, however, that the two fields are not mutually exclusive in this respect as there is plenty of room for engineering training and ability on the part of service-men. Mr. Eastman paid very generous tribute to the designing engineers for their accomplishments in recent years and spoke of the service-men as their younger brothers. He said, moreover, that the engineering, business and service elements of the automotive industry should dovetail closely. He warned the service-men not to tell everything they knew at this meeting.

J. W. Lord, service manager of Harrolds Motor Car Co., which handles the Pierce-Arrow product in New York City, presented a paper on the subject, Does Factory Organization Give Full Consideration to Service-Station Problems? He pointed to the fact that the public is demanding better, cheaper and more prompt repairs and that there is increasing realization that maintenance has not received the close study which has been given to automobiles from the production and the performance standpoints. He took as a theme that the manufacturer who can sell the most miles per gallon of reliable truck transportation is the one to whom the public will come with its transportation problems. There are fundamental service problems that must be solved while the vehicles are being designed and produced. There is a feeling in the field that the engineers in the factories are inclined to be arrogant and obstinate. Mr. Lord felt that this condition will be obviated as the factory engineer takes more interest in service problems and becomes more closely in contact with service and maintenance. He is of the opinion that the flat-rate service is the most satisfactory method of selling maintenance and that it will become general; also that the flat labor-rate plus the cost of material is liable to make the final charge to the customer greater. The maintenance of the flat-rate service depends on the possibility of doing the same job on any car or truck of given make and model in approximately the same time. With regard to the use of private parts, Mr. Lord pointed to the significant fact that the makers of these parts are doing a flourishing and growing business, concluding that it is not clear that their products are not giving fair service.

Past-President Bachman, who had prepared a paper in connection with that of Mr. Lord, said that in cases where the designing engineer can be criticised justly for arrogance the service-man is frequently reprehensible for the impetuosity with which he makes and supports assumptions. He explained that it is an arduous job for a designer to make and maintain personal contact with a multitude of dealers.

Mr. Bachman argued that undue merit has been claimed for flat-rate system, stating that it is not the only method which can be made satisfactory to the car user. To make the price for work acceptable it must appear in the buyer's mind to be fair and be based on an accurate method of determining the cost. There are flat-rate prices for service re-

(*Concluded on p.* 317)

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

FUEL WASTE, ITS CAUSES AND REMEDIES

THE Society of Automotive Engineers recently was requested to have representatives testify before the United States Senate Committee on Manufactures regarding the part that the Society is taking in the elimination of motor-fuel waste. The accompanying statement was prepared by members of the Research Committee in conference with the officers of the Society. This statement, as well as the oral testimony of two representatives of the Society, was made a part of the minutes of the Committee on Manufactures in connection with its investigation of the price of gasoline.

The Society's Interest in Economy

The Society of Automotive Engineers has a membership of about 5000, including practically all of the engineers engaged in the design and production of the various forms of power units using gasoline as a fuel. This includes passenger and commercial vehicles, aircraft, tractors, motorboats and stationary power units. It is purely an engineering and technical society, organized for the advancement of engineering knowledge in the lines above mentioned by cooperative discussion and research.

The Society is interested in the elimination of all forms of waste, including that of gasoline, the conservation of which is considered to be of particular importance. Gasoline has become a most important fuel because it has enabled us to place in the hands of almost everyone a prime-mover in small units capable of reasonably satisfactory operation even by the most unintelligent. Due to the lack of technical skill of the great majority of the operators, the tendency toward waste of fuel in operation is greatly increased. Changes in design of automotive apparatus except in the direction of more automatically correct operation does not offer as fruitful a field for improvement so far as economy is concerned, as does the education of the user along the lines of more intelligent operation of the vehicle.

Use and Waste of Oil

About 20,000,000,000 gal. of crude petroleum are used annually in this Country in producing the more than 5,000,000,000 gal. of gasoline, of which some 4,000,000,000 gal. is used by automotive vehicles for purposes of transportation. Of these vehicles, only a very small proportion are operated under centralized supervision that promotes the maximum economy of operation.

In the production and distribution of motor-fuel from crude petroleum, and in the use of this fuel, there is bound to be some waste as there is in all other commercial activities. Part of this waste is preventable by means already at our disposal. Other forms of waste, where prevention is probably possible, are the subject of concentrated study at the present time. The losses that occur in the manufacture and distribution of gasoline are not directly within the province of the automotive industry, and we will therefore confine ourselves in this statement to the preventable waste in the actual use of fuel.

Cost and Quality of Motor-Fuel

The quality of gasoline, which partly determines its cost and the economy with which it is used, evidently has a considerable bearing on the ability of the user to operate his vehicle with maximum efficiency. This feature of fuel production vitally concerns the automotive industry and has been the subject of research and development since 1912, under the auspices of the Society of Automotive Engineers and, further, of cooperative research under the joint direction of the engineers of the automotive industry, and of the petroleum industry as represented in the American Petroleum Institute.

Gasoline for motor-fuel has come to be the highest-priced quantity-product of petroleum, except lubricating oil, and the motor vehicle is the largest single user of both products. Neither of them has any competitor at anything like the present price, and petroleum, the source of both, exists only in quantities that may be exhausted in a comparatively short time. Hence the elimination of waste is as important for conservation as for the maintenance of a minimum fuel-cost. Unfortunately, low cost and conservation do not always go together. Insofar as the user is responsible for the elimination of waste, a higher cost offers more incentive for economy.

Fuel in the Engine

Essentially, the automobile engine consists of a number of cylinders in which a mixture of gasoline vapor and air is burned to produce pressure that is transmitted to moving pistons and applied as power to the crankshaft and thence to the wheels. The fuel must be vaporized and intimately mixed with air in the correct proportions at the time that ignition takes place to allow of efficient combustion.

The carbureter and the intake-manifold are designed to perform the function of mixing the correct amount of fuel with the air, and to distribute the resulting mixture to the cylinders. The mixing of the fuel and the air begins in the carbureter and, after continuing during the passage through the manifold, is completed in the cylinder. With the low-volatility gasoline now being supplied for motor-fuel, a considerable amount of heat is necessary for the proper mixing of the air and the fuel. This heating may be applied in different ways; by maintaining the cylinders at a proper temperature, or by supplying heat to the carbureter or the manifold or both. If the correct proportion of fuel to air is not used, or if the mixture is not distributed uniformly to the different cylinders, some fuel will be wasted.

As a matter of fact, it begins to appear that the adoption of means for maintaining the engine at a uniform operating temperature under all climatic conditions will go a long way to improve economy. Experience indicates that this temperature should be fairly high to obtain the most efficient operating results. The economical use of fuel is thus promoted not only by the better utilization of the fuel itself, but also by maintaining the engine lubrication at its maximum efficiency, producing the lowest engine friction. It has been proved that temperatures provided by holding the cooling water at or near the boiling-point are not too high. In addition, for use in cold climates, it may prove

desirable to provide extra heat at the carbureter and the manifold, especially at the time of starting, when the engine is cold.

Mixture Adjustment and Fuel Waste

A mixture may be too rich in fuel and still produce power, without any obvious bad effects to warn the operator that he is wasting fuel. In fact, double the necessary amount of fuel can be used in this way without the user being aware of it. Over-rich mixtures are commonly used for reasons given below. Tests by the Bureau of Mines of 100 or more trucks and passenger cars picked out at random on a city street have shown that, in the average operation of trucks and passenger cars, 25 per cent of the fuel drawn into the engine passes out of the exhaust unburned.

The causes of waste of this kind are chargeable partly to the designer and partly to the user of the vehicle, or to the mechanic who attends to the adjustment. Practically all fuel-systems require adjustment to give the correct fuel-mixture. If these adjustments are not properly made, the waste of fuel may be 50 per cent, and probably the average loss in practice is at least 20 per cent. Owing to the large number of unintelligent and careless drivers who operate cars, it would be better if the carbureter setting and other adjustments could be made at the factory but, owing to variations in the fuel and in the weather conditions, this has not proved feasible up to date.

If the carbureter is constructed so that the correct mixture is not supplied under all driving conditions without continual hand-adjustment, or if the mixture between the fuel and the air is not sufficiently complete at the time of ignition, there will be a waste that no amount of care in adjustment can prevent. As to the question of a sufficiently intimate mixture, this involves the complete design of the powerplant, including the carbureter, manifold and engine, it being understood that the final mixture is produced by a violent agitation with the addition of heat. There is little doubt that one-half of the cars in use are deficient in design in the respects that make for a proper mixture of the fuel and the air before ignition, and that the fuel-consumption of these cars could be reduced at least 20 per cent by slight modifications in design and, in many cases, by simply replacing the parts that make up the fuel-system by others that are more efficient and already available.

Researches to Promote Economy

The causes of the excessive use of fuel have been under investigation by the Research Committee of this Society since 1919. A Report was published in 1920 to give the designers and service departments the latest information on the design of intake systems to secure economy of fuel. Although this report is only about two years old, much of the information given in it has been superseded by later developments. The same general subject is being investigated by the United States Bureau of Standards, which has already produced results making possible savings of millions of dollars worth of motor-fuel. Some of these savings are being realized in the operation of motor vehicles by the Post Office and other Government Departments.

Another direct source of fuel waste is the bad mechanical condition of many automobile and truck engines in service. Worn or improperly adjusted pistons and valves and ignition failures all waste fuel. Waste of this kind is a question of design and construction insofar as these bear on the proper functioning of the various parts, their durability and ease of repair. Its prevention is to a far greater extent in the hands of the various operators. It is obviously very difficult to predict the possible saving in this direction. All causes of mechanical friction, such as badly adjusted brakes and bearings and lack of oil, absorb power and waste fuel.

One of the main objects of the Society is the elimination of fuel waste by improvements in design, construction and methods of upkeep. Direct waste of fuel has received the most attention, as it represents the greatest preventable loss. Within the past 5 years, some 50 technical papers and reports have been published in The Journal of the Society on this subject alone. The main reason for this activity is the fact that commercial gasoline as sold to the consumer was becoming more and more difficult to use with economy. Gasoline is a mixture of different constituents having different degrees of volatility or ease of vaporization. Up to about 1912, commercial gasoline contained only the most volatile constituents and offered no difficulty in vaporizing for producing a satisfactory mixture for use in the simplest type of engine. With the increasing demand it became necessary for the producer to include heavier and less volatile constituents that require more heat for their vaporization and, as this process went on from 1912 to 1920, the utmost efforts of the designers were necessary to keep pace with the change in fuel and maintain reasonable economy.

Accomplishment of American Automotive Engineers

In fact, we believe that the American automotive engineer is even now in advance of all others in the technique of economical fuel-utilization. In dealing with the fuels of low volatility marketed is this Country he has learned much as to the behavior of fuels in the engine and has profited by this knowledge in the design of efficient vehicles. European cars average more miles to the gallon than American cars but, when reduced to a common basis of weight and reserve power, the American cars are superior in economy. Due to high fuel-cost and taxation, European design has tended to attempt to secure high mileages by a reduction of the weight and the reserve power. The demand of American car-users, partly due to the poor condition of roads, has called for the heavier weight and the greater reserve-power of average American cars.

In accomplishing this result the designer has had to overcome the practical difficulty of meeting the demand of the automobile user mentioned above. High power, which is only rarely used, and the ability to take steep grades and accelerate rapidly without changing gears, which is demanded by the public in passenger cars today, are incompatible with maximum fuel-economy. This high power, which is only occasionally used, introduces features of design that result in fuel waste and also encourages a carbureter adjustment that is wasteful since maximum power in any engine is never associated with minimum gasoline consumption. The amount of fuel used to obtain the above characteristics may be 50 per cent more than that which would be required were maximum mileage per gallon the chief consideration. Moreover, the desire for starting-off quickly at full power in cold weather before the engine has become heated tends toward a still further excessive use of fuel. The average driver appears to desire to have his fuel system adjusted to give the maximum power and a quick getaway in cold weather, perhaps because he does not know the penalty he is paying in fuel waste.

Responsibility of the Driver

To illustrate what this means, we would say that our best information indicates that a majority of 1-ton cars in the hands of average drivers actually cover not more than 16 miles per gal. of fuel. We are convinced that, if these same cars were more carefully designed and provided with a more satisfactory means for supplying the correct fuel-mixture, they would average under the same operating conditions 20 miles per

gal. instead of 16, and that a further improvement of at least 25 per cent would be possible through more careful operation by drivers.

The fuel waste in commercial vehicles seems to be even worse. Some fleets of commercial vehicles weighing about 4 tons including load average only 5 miles per gal. of fuel, while others of equal weight and in about the same service average 12 miles per gal., the differences being due partly to differences in design and equipment and partly to differences in the care with which the various adjustments are made and the operation of the vehicles is conducted.

It should be noted that the automotive industry as it exists in this Country is only about 10 years old. Not only have most of the engineers and manufacturers been trained in that brief period but the rapid expansion of the use of motor vehicles has introduced new and untrained drivers at the rate of about 1,000,000 per year. The production of vehicles to meet the demands of these untrained users has made the building of really economical units doubly difficult.

Effects of Fuel Volatility Investigated

Gasoline waste depends partly upon the quality or the volatility of the fuel used for the reason that the volatility affects its adaptability as a fuel for the engine consuming the greater part of this product. But the greater the quantity is of gasoline made from a barrel of crude oil, by any given process, the lower the volatility is. The best interests of the public, as well as of the automotive and oil industries, will plainly be served by obtaining a maximum amount of satisfactory fuel from each barrel of crude. To accomplish this, it is necessary to know how heavy a grade of gasoline can be used in average vehicles without disproportionately increasing the amount of fuel consumed, or the difficulty of operation. About a year ago the oil and the automotive industries determined to attempt to obtain an answer to this question by means of a joint research. Several refineries furnished special fuels for the purpose and 10 automobile companies undertook, each independently, an extensive research program, under the supervision of the Research Committee of this Society.

Some features of such a research could best be handled by an impartial third party who might be said to represent the public, and we have felt ourselves very fortunate in having in the Bureau of Standards an organization and equipment capable of taking up certain lines of this investigation and carrying them out in the most efficient manner. It was therefore decided to turn some of the most important questions over to the Bureau of Standards for determination and to aid the Bureau by the loan of materials and assistants from both the industries engaged in carrying out the work. This investigation at the Bureau of Standards has been in progress for less than a year and it is obvious that any final determination in a matter so important and complicated as the one under discussion could not be arrived at in that length of time. On the other hand, there are indications from observations made up-to-date that a quality of gasoline may be used in automotive vehicles with a reasonable degree of satisfaction and economy, in summer at any rate, which will alone make possible an increase of some 30 per cent in the amount of gasoline that is producible from every barrel of crude oil.

Summary of Factors Affecting Economy

The several factors that promote fuel economy may be summarized briefly as follows:

(1) Universal adoption of means for maintaining the engine and the carbureter and intake system at the best operating temperature

(2) The adoption as rapidly as possible of carbureting devices that can be adjusted once for all by the maker to supply automatically a correct amount of fuel as completely atomized as possible for economical operation under all conditions

(3) An economically correct grade of gasoline supplied uniformly throughout the Country but suitably varied if possible to meet climatic conditions. Uniformity of fuel would go far to make possible the adoption of the more economical carbureting systems suggested above.

(4) Education of the user of motor vehicles to the advantages that will accrue to him through fuel economy. These advantages are in reality much greater than the saving in fuel cost. They include also less wear in the engine, less carbonization, less upkeep cost and freedom from other minor annoyances

(5) The gradual adoption of engines using higher compression-ratios, with resulting higher fuel-economy. This can be accomplished only as improvements in design or in the quality of the fuel make higher pressures possible without engine knock, which at present limits the usable compression-pressures

(6) Servicing of automotive equipment to maintain it in satisfactory condition for economy of operation. This refers to the entire vehicle as well as to the engine, and present conditions can be improved by the education of the public and of the garage mechanic, and by improvements in the service facilities offered by the dealers

All of these factors, except perhaps the education of the general public, are receiving a continually increasing amount of study by the Society of Automotive Engineers and the manufacturers and we believe that much has already been accomplished in eliminating fuel waste. The necessity of meeting popular demands inconsistent with economy, and the difficulty of putting new developments into immediate production, have retarded this accomplishment. Even more important perhaps is the fact that the average vehicle now in use is a product of 2 or 3 years ago, not of today.

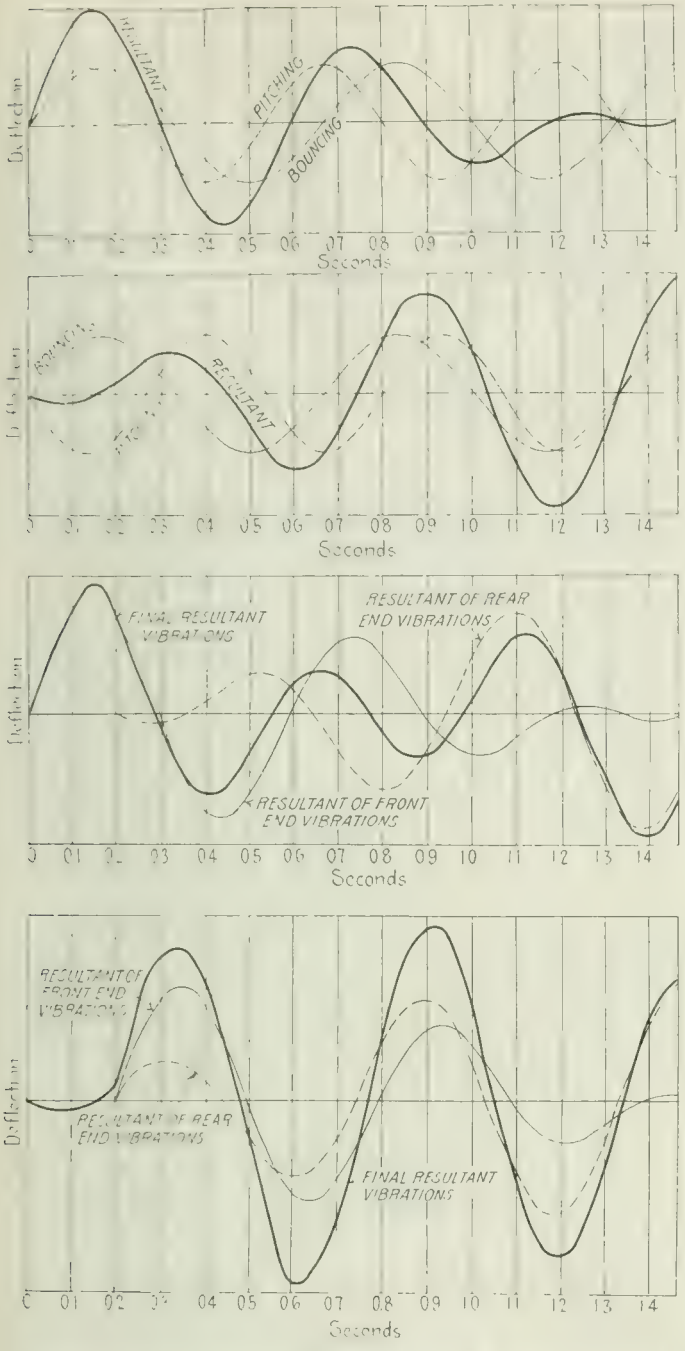
NOTES ON SPRING ACTION

It is a well-known fact that automobiles having apparently similar suspension systems are often widely different in springing qualities. Why this should be is likely to remain a mystery until we have at least the elements of a rational theory of spring action in automobiles. Although a general theory is lacking, the mechanics of spring-fitted vehicles has been studied by a number of investigators who have deduced a few theorems that point to certain vehicle constants as possible factors in the suspension problem. These factors are the periods of vibration, the axes of oscillations and the distribution of weight in the body.

Periods of Vibration

Akimoff in his paper entitled Remarks on the Dynamics of the Automobile[1] has shown that Lagrange's method of analysis leads to two distinct formulas for the periods of plunging and pitching respectively. Using the same method, we have generalized Akimoff's formulas to apply to an auto-

[1] See Transactions, vol. 12, part 1, p. 141.



Vibration of the Front End after the Front Wheel Has Hit an Obstruction

Vibration of the Rear End after the Front Wheel Has Hit an Obstruction

Resultant Vibration of Front End as Combined from the Individual Vibrations of Each End

Resultant Vibration of Rear End as Combined from the Individual Vibrations of Each End

FIG. 1—EXAMPLES OF THE SUPERPOSITION OF BOUNCING AND PITCHING VIBRATIONS

mobile in which the front and the rear springs are not the same and in which the center of gravity is not limited to a horizontal position half-way between the axles. We find that bouncing, or straight up-and-down vibration; pitching, or oscillation about a transverse horizontal axis; and rolling, or oscillation about a longitudinal horizontal axis, are all generally present simultaneously. The formulas for the periods of bouncing, pitching and rolling are

$$B = 2\pi\sqrt{([W/g] \times [1/(m+n)])} \quad (1)$$

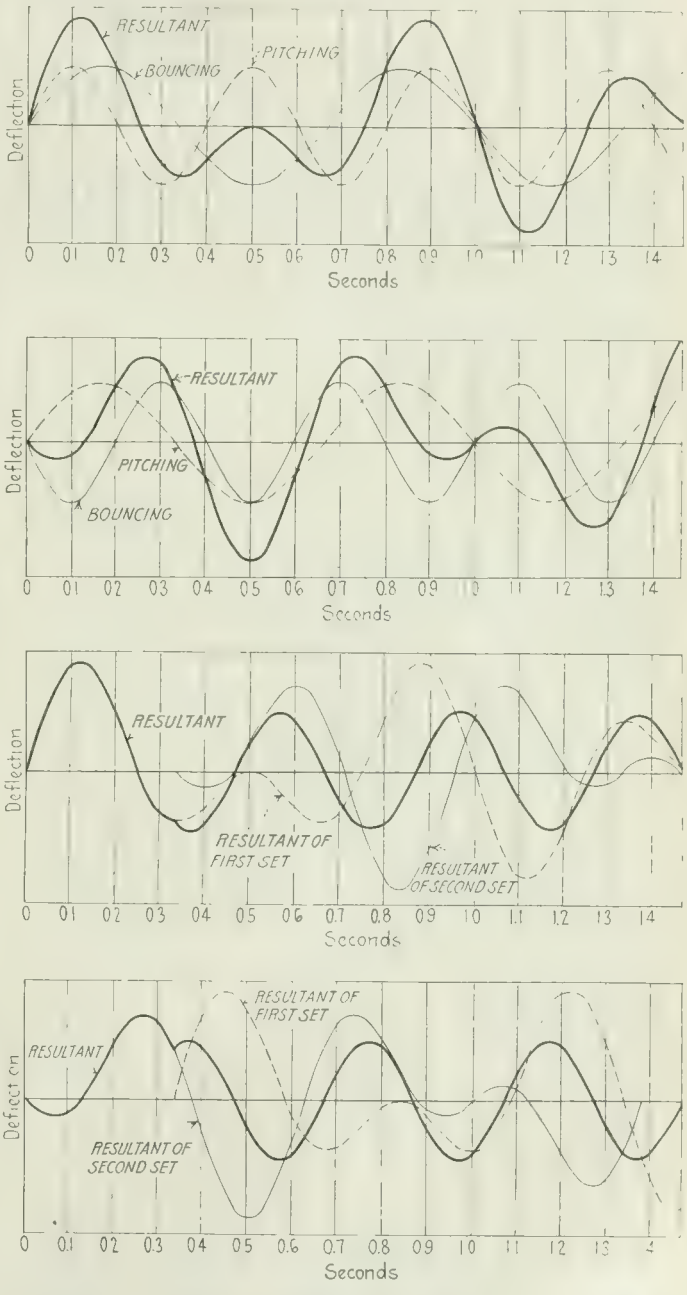
$$P = 2\pi\sqrt{([W/g] \times [k^2/(a^2m+b^2n)])} \quad (2)$$

$$R = 2\pi\sqrt{([W/g] \times [abr/(2c^2[a^2m+b^2n])])} \quad (3)$$

where

a = the horizontal distance of the center of gravity from the rear axle
b = the horizontal distance of the center of gravity from the front axle
c = the track
g = the acceleration due to gravity, 32.2 ft. per sec. per sec.
k = the radius of gyration about the axis of pitching
m = the constant for one rear spring
n = the constant for one front spring
r = the radius of gyration about the axis of rolling
W = the weight of the car body

By making $a = b = 1$ and $m = n = W/2\delta$, where δ is the



Vibration of the Front End after the Front Wheel Has Hit an Obstruction

Vibration of the Rear End after the Front Wheel Has Hit an Obstruction

Resultant Vibration of the Front End as Combined from the Individual Vibrations of Each End

Resultant Vibration of the Rear End as Combined from the Individual Vibrations of Each End

FIG. 2—ANOTHER EXAMPLE OF THE SUPERPOSITION OF BOUNCING AND PITCHING VIBRATIONS

initial deflection of the spring, our formulas reduce to those given by Akimoff in his paper.

$$B = 2\pi\sqrt{(\delta/g)}$$
$$P = 2\pi\sqrt{[(\delta/g)\times(K^2/l^2)]}$$

The ratio of the first two vibrations is

$$P/B = k\sqrt{[(m-n)/(am-bn)]} \qquad (4)$$

Since the location of the center of gravity and the radius of gyration are determined by the distribution of the weight, formula (4) suggests that, if the riding qualities are influenced by changes in this ratio, the designer has it in his power to select favorable values for these variables.

As an indication that ease and comfort in riding might be affected by even slight changes in period, we may cite the measurements of Broulhiet[2], who showed that the periods of European cars varied between the extreme limits of 0.8 and 0.5 sec., or 75 and 120 vibrations per min. Only two exceptionally fine-riding cars had as low a period as 75 vibrations and cars having a period approaching 120 vibrations per min. were almost unbearable.

Axis of Oscillation

The radius of gyration k in formula (4) implies an axis about which the body rotates to-and-fro. The position of this axis has been defined by A. Herdner[3] for any vehicle supported by springs on any number of axles carrying wheels of any diameter. Reduced to the case of the automobile, Herdner's theorem fixes the axis for pitching in the plane connecting the two axles, at distances from the axles inversely proportional to the spring constants. For example, if $m:n::1.0:1.5$ the axis of pitching will divide the wheelbase in the ratio of 0.4 to 0.6 and will be nearer the front axle.

Herdner's proof needs some revision to be strictly applicable to the type of suspension used on automobiles, but this cannot change the main features of his theorem according to which the position of the axis of oscillation is fixed by the spring constants and is in no way dependent on the distribution of weight in the body.

The position of the axis of oscillation and the radius of gyration are connected by the relation

$$k^2 = d^2 + K^2$$

where

d = the distance of the axis of oscillation from the center of gravity
K = the radius of gyration about a parallel axis through the center of gravity of the body
k = the radius of gyration about the axis of oscillation

Weight Distribution

The range of values assumed by K for various automobile bodies is not known at present, and it is therefore not possible to evaluate (4). It may be profitable however to attempt an approximation and for this purpose we shall choose springs having the ratio of constants $m:n::1.0:1.5$. Under these conditions, (4) becomes

$$\sqrt{[2.5/(a^2+1.5b^2)]}\times\sqrt{[(K^2/l^2)+([b/l]-0.4)^2]} \qquad (5)$$

if we neglect the height of the center of gravity above the plane of the axles.

We know that K/l must be less than ½ and probably greater than $1/\sqrt{12}$. Possible values for automobiles are 0.3 to 0.4 and these values substituted in (5) yield the results given in Table 1 for different positions of the center of gravity.

TABLE 1—INFLUENCE OF THE CENTER OF GRAVITY

b/l	$\sqrt{[2.5/(a^2+1.5b^2)]}$	r^2/l^2	$K/l=0.4$	$K/l=0.3$
0.50	2.00	0.0100	0.826	0.634
0.55	1.96	0.0225	0.837	0.658
0.60	1.89	0.0400	0.846	0.683
0.65	1.82	0.0625	0.860	0.708

We conclude from these figures that the difference in the periods of plunging and pitching are probably large enough to affect seriously the resultant motion to which the occupants of the car are subjected, but that the body-designer's control over the ratio of the periods is slight, at least when the spring constants are fixed.

The presence of passengers decreases K/l but, unless the seats are equidistant from the center of gravity, which is usually not the case, r also changes; how this affects the value of $k^2=r^2+K^2$ cannot be predicted. This point may be worth while investigating because of its bearing on the designer's control over springing quality.

Superposition of Vibrations

The radius of gyration and the axis of oscillation are involved also in the relation between the amplitudes of vibration and the forces causing the vibration. Little is known of the numerical size of the forces transmitted through the rubber-tired wheels to the body, but fortunately, the force enters the expressions for both amplitudes, of bouncing and of pitching, in the same way, and this circumstance permits a determination of the ratio of the amplitudes.

If we have the ratio of the amplitudes, as well as of the periods, we can determine the type of the resultant oscillation. Figs. 1 and 2 illustrate this for the front and rear ends of the car-body in the simple case of a vehicle drawn as a trailer at constant speed along a smooth road on which there is one sharp obstruction placed perpendicularly across the path of the vehicle. In both figures, the ratio of amplitudes is taken as 1, and the bouncing vibrations as 9 per min.; the ratio of periods is taken as 0.8 in Fig. 1, and as 0.6 in Fig. 2. The heavy lines are the resultants obtained by adding the ordinates of the vibrations. In each figure, the two upper groups of curves show the resultant oscillation of the front and rear ends respectively of the body, caused by the impulsive force due to the front wheels passing over the obstruction, and the other two groups show the effect of superposing on the first two groups the additional bouncing and pitching vibrations caused by the rear wheels meeting the obstruction after an interval determined by the wheelbase and the speed. The figures are drawn for a wheelbase of 120 in. at a speed of 15 m.p.h. for Fig. 1 and of about 13 m.p.h. for Fig. 2 as may be taken from Table 2.

TABLE 2—TIME TO PASS OVER WHEELBASE LENGTH AT VARIOUS SPEEDS

Speed, M.P.H.	Speed, Ft. per Sec.	Time to Pass Over 120 In., Sec.
10	14.7	0.71
13	19.1	0.52
15	22.0	0.45
20	29.3	0.32

Note that the amplitude depends on the ratio of the speed to the wheelbase and that there are ranges of speed for the minimum and the maximum shock. An extension of this method to any type of road seems possible by utilizing the studies made by Liebowitz, Napier, Baillie and others on the behavior of a single rubber-tired wheel.

Conclusion

The fragmentary theory that is implied in the combined work of Akimoff, Herdner, Broulhiet and Nadal[4] proposes to attack the suspension problem from two angles

(1) By assigning a definite and important rôle to the weight-distribution constants of the body
(2) By studying the resultant curves obtained by superposing the harmonic motions due to bouncing, pitching and rolling

In this paper we have sketched only the barest outline of this program, in the hope that interest may be aroused in the experimental verification without which this germ of a theory of springing must remain a collection of academic theorems.

[2] See *Revue de l'Industrie Minérale*, vol. 1, part 2, p. 87.
[3] See *Revue Générale des Chemins de Fer et des Tramways*, vol. 28, No. 6, p. 379.
[4] See *Annales des Mines*, vol. 2, p. 413.

Current Standardization Work

DURING the last month only a few Division meetings were held because the majority of the subjects awaiting Standards Committee action have been assigned to Subdivisions that are preparing reports for consideration at the Division meetings that will be held during March and April. It has been found that only through the assignment of subjects to definite Subdivisions for the preparation of preliminary reports can the Division work be carried on most advantageously with respect to the time of the Division members necessary in attending the meetings and the expense incurred through such traveling and absence from their regular engineering work.

The Society letter-ballots on the adoption of the standards recommendations approved at the Standards Committee Meeting in January will be counted on March 12 and the data sheets containing the standards adopted by letter-ballot issued in the latter part of the month.

Paints, Varnishes and Enamels

The following Subdivision on Paints, Varnishes and Enamels has been appointed by Chairman G. E. Goddard of the Passenger-Car Body Division:

J. Warren Armitage	John L. Armitage & Co.
Henry A. Gardner	Paint Manufacturers' Association
J. O. Hasson	Sherwin-Williams Co.
C. D. Holley	Acme White Lead & Color Works
L. D. Pulsifer	Valentine & Co.
W. J. Schlinger	Flint Varnish & Color Works
C. C. Schumann	Pratt & Lambert

Passenger-Car Door Hinges

At one of the early meetings of the Passenger-Car Body Division the importance of standardizing certain types of door hinges was realized and E. G. Simpson, of the Fisher Body Corporation, was appointed a committee of one to formulate a tentative proposal for consideration.

Seven standard hinges have been recently proposed by Mr. Simpson for concealed and outside door-hinges of the following types:

Closed-Body Guide Hinge — Closed-Body Strap Hinge
Open-Body Short Guide-Hinge — Open-Body Long Guide-Hinge
Open-Body Concealed Hinge — Closed-Body Concealed Hinge
Malleable-Iron Strap-Hinge

The proposed standards have been based on present practice and are intended to meet the requirements of the majority of the companies. Comments thereon are being obtained from body builders.

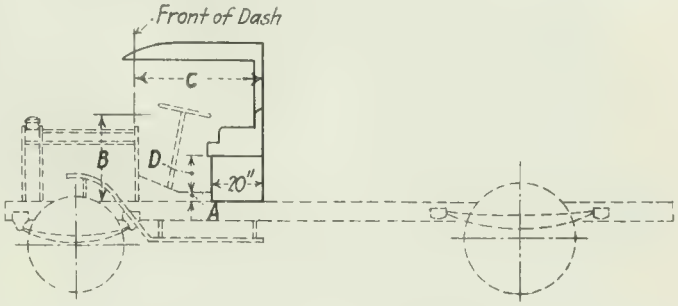
Motor-Truck Cabs

A meeting of the members of the Truck Division was held in the offices of the Society on Jan. 8, the day preceding the Standards Committee Meeting, to discuss the proposed S.A.E. Recommended Practice for Motor-Truck Cabs, that was printed in the December issue of The Journal, in conjunction with the comments thereon received from chassis and cab producers. It was decided to take no final Division action on the tentative recommendation, but to make what changes were deemed desirable and to submit the proposal to chassis and cab builders for comment with the understanding that final action would be taken at the next Division meeting to which cab builders would be invited to send representatives.

In view of the criticisms as to the widths specified, it was considered best to eliminate the width, as it is not necessary to obtain interchangeability of cabs in chassis. It was thought that it would be desirable to have a separate classification for speed-wagon cabs. As the Division members are not in the position to recommend the mounting dimensions, recommendations will be obtained from the cab builders as to desirable practice.

The dimension specified for the distance from the chassis to the windshield lower edge was changed to 36 in. for both sizes of cab, but it was felt that this dimension should be carefully considered by the cab builders before final approval.

The tentative Division recommendation as finally revised is given in the accompanying illustration.



PROPOSED MOTOR-TRUCK CAB DIMENSIONS

Truck Capacity, tons	A	B[1] Min.	C	D Variable
Under 2[a]				
2 to 3	3½	36	46	15½±1
Over 3	3½	36	46	15½±1

[1] Dimension B is from the top of the chassis frame to the lower edge of the windshield.
[a] This classification covers speed-wagons for which cab dimensions are to be standardized if feasible.

Passenger-Car Front-Wheel Hubs

Detailed dimensions for passenger-car front-wheel wood hubs were decided upon tentatively at a meeting of the Axle and Wheels Division in Chicago on Jan. 30. The dimensions, which are given in the accompanying table, are intended to constitute an extension of the recommendation approved by the Standards Committee on Jan. 9.

PASSENGER-CAR FRONT-WHEEL WOOD HUBS

Hub Size	Outside Diameter of Hub	Distance Between Flanges	Flange Diameter	Flange Fillet-Radius	Bolt-Circle Diameter	No. of Bolts	Bolt Size	Hub-Cap Thread
R0	2.1830 2.1860	1¼	6	⅜	5	6	⅜	2⅛ 24
R1	3.0625 3.0655	1¼	7	¼	5¾	12	7/16	2 9/16-16
R2	3.5000 3.5030	1⅜	7¼	¼	6	12	7/16	2 9/16 16
R3	3.6875 3.6905	1½	7⅝	⅜	6¼	12	7/16	3 -16
R4	3.8125 3.8155	1¾	8	⅜	6¼	12	7/16	3⅛ 16

Note: The data in the table apply to wheels with wood or steel felloes, that is to all wheels having wood hubs.

Radiator Nomenclature

The meeting of the Radiator Division, held on Jan. 29 in the rooms of the Old Colony Club at the Hotel LaSalle in Chicago, was attended by J. D. Harris, McCord Mfg. Co., Inc., chairman of the Division; H. B. Knap, Packard Motor Car Co.; Charles Oppe, G & O Mfg. Co.; Fred. M. Young, Perfex Radiator Co.; and Standards Manager R. S. Burnett.

In connection with the nomenclature of radiator cores, it was felt that the term "honeycomb" should not be used because it is inadequately descriptive. It is a trade term that is frequently applied to several types of radiator.

Chairman Harris presented four definitions that he had based on those suggested to the Division by Herbert Chase,

that were printed on p. 127 of the January issue of THE JOURNAL. After carefully studying the definitions proposed, it was decided to recommend the addition of the following definitions, as "Group 3—Types of Radiator Core," to the S.A.E. Standard for Automobile Nomenclature, page K5 of the S.A.E. HANDBOOK.

Group 3—Types of Radiator Core

Individual Fin-and-Tube Type.—A number of tubes of any cross-sectional form to each of which are attached gills or fins of circular, square or other shape, each tube and its fin or fins forming a separate unit.

Continuous Fin-and-Tube Type.—A number of tubes of any cross-sectional form assembled and joined together by fins or plates.

Ribbon Cellular Type.—A number of water passages formed by joining metal ribbons at the edges, the water-passage walls usually being crimped and grouped to form a cellular structure. Parts of the cellular structure may be formed by flat or crimped ribbon that is not a part of the water passage.

Air-Tube Cellular Type.—A number of air-tubes nested in such a way as to form water passages, being sealed at the ends of the tubes. In this type the water can flow transversely as well as vertically around the tubes.

The present radiator nomenclature in the S.A.E. HANDBOOK was revised to include the terms used in connection with the S.A.E. Standard for Radiators, p. A26 of the S.A.E. HANDBOOK, so as to have the nomenclature complete, each type of radiator being covered separately as follows:

Group 2—Radiators

Shell Type

Radiator upper tank
Radiator filler neck
Radiator filler cap
Radiator inlet fitting
Radiator tie-rod fitting
Radiator overflow tube
Radiator lower tank
Radiator outlet fitting
Radiator drain-cock
Radiator anchor stud or bolt
Radiator anchor stud or bolt plate
Radiator side bolting-member
Radiator shell
Radiator supports
Radiator hinge-rod fitting
Radiator hood-ledge liner

Cast Type

Radiator upper tank
Radiator filler cap
Radiator inlet fitting
Radiator tie-rod fitting
Radiator overflow tube
Radiator lower tank
Radiator outlet fitting
Radiator drain-cock
Radiator anchor stud or bolt
Radiator anchor stud or bolt plate
Radiator sides
Radiator clamping strips
Radiator header gasket
Radiator inlet gasket
Radiator outlet gasket
Radiator hinge-rod fitting
Radiator hood-ledge liner

SHEET STEEL

At the joint meeting of the Society's, the American Society for Testing Materials and the American Society for Steel Treating Sheet Steel Committees on Jan. 8, 1923, a Committee on Testing of Sheet and Strip Steels was appointed consisting of J. M. Watson, chairman, Hupp Motor Car Co.; C. N. Dawe, Studebaker Corporation of America; F. E. McCleary, Dodge Bros.; Jack Dailey, General Motors Corporation; L. A. Danse, Cadillac Motor Car Co.; and E. W. Upham, Maxwell Motor Car Co.

The Committee was given full power to fix the methods of testing and to obtain help from men not on the Committee. All tests are to be made in the manner prescribed by the Committee, which will send monthly reports on the work to the Standards Department of the Society for distribution among the Subdivision members. As all of the members of the testing committee are located in Detroit, it is felt that rapid progress can be made.

STEEL FELLOES FOR WOOD WHEELS

Letters proposing the standardization of the tenon-holes in steel felloes for wood wheels were discussed at the January meeting of the Axle and Wheels Division. It was argued that while there is practically a standard among the wheel manufacturers at the present time, a published standard would be helpful. The dimensions given in the accompanying table were approved tentatively for adoption as S.A.E. Recommended Practice.

DIMENSIONS OF TENON-HOLES FOR STEEL FELLOES

Pneumatic-Tire Size, In.	Spoke Size, In.	Diameter of Tenon-Hole, in.
3½-4	1¼	½
4	1⅜	⅝
4½	1½	⅝
5	1¾	¾

As "giant" pneumatic tires are not used on steel felloes, it was not felt necessary to include tire sizes above 5 in.

TIRE CLEARANCES

A suggestion of the American Chain Co. that the clearance between tires and fenders be standardized has been referred to the members of the Passenger Car Division for study.

In making this suggstion, J. R. Rayburn, of the American Chain Co., stated that

> It would seem of prime importance to provide a minimum clearance behind and ahead of the tires in a horizontal direction, preferably 3 in. The vertical clearance above the tires depends upon the extent of the spring action.
>
> We have found fender braces over tires free to contact with the tire on extreme spring compression. When this happens with chains attached, either the chains or the fender bracket must fail.

TOOL STEEL

Carbon tool-steel specifications have been tentatively approved by the Sub-Sub-Committee of Committee XIV of Committee A-1 of the American Society for Testing Materials. Copies of these specifications, which cover six classes of carbon tool-steel as determined by the chemical compositions, have been sent to the members of the Iron and Steel Division for comment.

The specifications cover the purposes for which the classes are frequently used; process of manufacture, crucible or electric-furnace; annealing; chemical composition; methods of analysis; permissible variations in dimensions; finish; marking and inspection and rejection.

SOCIETY MEETINGS

(*Concluded from p.* 309)

pairs of the most ordinary character which are obviously not justified. Much value lies in the flat-rate system in that it necessitates careful analysis of operations. Outside of the variation in labor and time that may result from the difference in individual conditions on the same class of job there is the more serious matter of variation in the amount of material required to do a first-class job under different conditions. Mr. Bachman felt that these variations cannot be properly provided for in the flat-rate system and that an overcharge in some cases and an undercharge in others are inevitable. One of the most interesting statements Mr. Bachman made was that there has been little or no demand for economical automobile transportation as opposed to cheap automobiles, and that it is probable that a product based on the former demand would be a failure. He said, however, that there is no doubt that shortly there will be a public demand for economy in automobile operation, which will be made possible by numerous factors, including highway development and general distribution of repair facilities.

Past-President Vincent contributed to the discussion of the papers mentioned above. He expressed doubt whether the averaging of repair costs as between cars that are well taken care of and those that are neglected is worse from the owner's standpoint than the fact that on a time and material basis the owner who is lucky enough to draw the fastest man in the service-station has an advantage. In addition, the man who takes care of his car will not need to have repair work done so often. Vehicles are designed to give good all-round results in territories varying greatly as to road and weather conditions. Mr. Vincent felt that the flat-rate system of service is fair, more businesslike and conducive to efficiency in the relations between the service-station and the vehicle owner. He said further that service-field suggestions, properly analyzed and checked, have resulted in refinement of car models.

O. E. Hunt, chief engineer of the Chevrolet Motor Co., concurred in the view that the average factory engineering organization is not closely enough in touch with service problems. He said that car builders will succeed in the proportion that they convince their customers that they are giving comfortable and dependable transportation at a less cost than their competitors are giving it.

A. J. Scaife, of the White Motor Co., expressed the opinion that it is difficult to get a large engineering organization aroused to the necessity of giving due consideration to complaints as to failure in service. He spoke of the merit of the car builder having representatives in personal contact with dealers, fleet owners and individual customers, as this results in bringing the customer's viewpoint directly to the attention of the engineering staff.

R. E. Fielder, chief engineer of the Fifth Avenue Coach Co., specified the fundamental requirements in the procedure of the operating engineer as being accessibility, simplicity, independent unit-construction, light-weight units that are easily handled, elimination of surplus refinements, fool-proof and accessible adjustments, and lubrication devices that are accessible and have adequate storage capacity. He believed that the time is near at hand when the operating engineer will determine which is the best type of vehicle to purchase.

C. B. Veal was of the opinion that the whole problem discussed resolves itself almost entirely into one of management and not of a difference of opinion between the designing engineers and the service-men. James Florida, of the Packard Motor Car Co. of New York City, said that in his opinion the flat-rate system has come to stay, as it not only increases efficiency in repairing cars but assists the owner in reducing his maintenance cost. Ralph Rognon, who conducts a large independent service-station in New York City, made a plea for planning development in service. He said much could be done along the lines of the standardization work of the Society. Past-President Manly made the point that the fundamentals of service are integrity and efficiency, neither one of which is worth much without the other; combined they will be effective in a flat-rate or any other system. Service Manager Trend, of the Maxwell-Chalmers Co., said that some factory service-departments constitute too great a barrier between the service-men and the designing engineers. Azel Ames, of the Advisory Board of the Metropolitan Division of the American Automobile Association, offered on behalf of car-owners cooperation in the solving of service problems.

Views were advanced by various speakers to the effect that some service-departments receive no cooperation from the factory engineers; that the latter do not visit the former even when they have a chance to do so; that no two jobs involve the same amount of work in the shop, and contrariwise that there is very little difference in the amount of time consumed as between different jobs. One service-man said that in operating, by giving the customer estimates as to the minimum and the maximum expense, only 7 out of 700 customers complained of overcharges. Another speaker said that in 18,000 operations the average time consumed was 36 min. for each.

In closing the session, Chairman Eastman said that he favored the flat-rate system but that he felt the public will have to be convinced of its merit; that is, made to understand the premises and conditions on which it is based.

NEW ENGLAND TO DISCUSS ECONOMICS

Harry Tipper, whose opinions on merchandising and the economic phases of the automotive industry are respected highly, will address the New England Section at the Engi-

Schedule of Sections Meetings

MARCH

2—Detroit Section—Painting Practice and Problems from the Chemist's Viewpoint—L. Valentine Pulsifer.
2—Washington Section—Engineering from the Service-Man's Viewpoint
7—Minneapolis Section—Development of the Modern Airplane—Charles Boehnlein
15—Metropolitan Section—Possibilities in the Development of the Trolley Bus—William P. Kennedy
16—Buffalo Section—Impressions of the New York City and Chicago Automobile Shows—J. Edward Schipper
16—Cleveland Section—The Value of the Consulting Engineer to the Automotive Industry—James A. Guthrie
16—New England Section—Economic Phases of the Automotive Industry—Harry Tipper
23—Mid-West Section—Road Lighting—F. H. Ford

neers' Club in Boston, Friday evening, March 16. This meeting occurs during the week of the Boston Automobile Show. It has been the custom of the Section to devote its meetings during show time to the commercial rather than the engineering problems of the industry. Mr. Tipper's talk will be followed by a showing of the North East Electric Co.'s latest animated pictures of starting, lighting and ignition apparatus. An informal dinner will precede the meeting at 6:30 p. m.

TWO MEETINGS ON LUBRICATION

W. F. Parish, lubrication engineer, addressed the Indiana Section on the evening of Feb. 15. His paper presented recommendations and experience relating to the Practical Application of Lubricants. Extremely cold weather affected the meeting attendance but those who defied the low temperatures enjoyed the paper very much. George Weidely, Lon R. Smith, Charles Trask and O. C. Berry took an active part in the discussion. Plans for the March meeting of the Section had not been completed definitely at the time of going to press.

A. Ludlow Clayden addressed the Pennsylvania Section on Feb. 20, presenting in an interesting manner some of the fundamentals of lubrication. The Pennsylvania Section will hold no meeting during March.

RECENT ADVANCES IN AERONAUTICS

Washington Section Hears About Work of Navy and National Advisory Committee

Members of the Washington Section at the monthly meeting held on Feb. 2 were entertained by two very instructive papers. The first, by Lieut. B. G. Leighton, who is in charge of aeronautic engine development in the United States Navy, described the Recent Developments in Aircraft Engines in the Navy; the second, by George W. Lewis, executive officer of the National Advisory Committee for Aeronautics, discussed the progress that has recently been made in aeronautic research.

Confining himself closely to the subject and believing that an aircraft is only as good as the powerplant that sustains and propels it, Lieutenant Leighton outlined the trend of the successive improvements in engines that have increased the safety, durability, dependability and economy of aircraft. He showed that the standard of excellence has been gradually raised from the original 50-hr. test, which consisted of a series of 5-hr. runs at from 90 to 100 per cent of the rated output without failure of a "major" part, to the present requirement of 300 hr. of continuous running with wide-open throttle at sea-level. This would represent about 600 hr. of normal flying-service, and at a speed of 75 m.p.h. would be equivalent to about 45,000 miles of cruising. By successively redesigning the parts that have caused break-downs the maintenance cost has been reduced, the weight per brake horsepower and per inch of piston-displacement has been decreased, and the fuel consumption per brake horsepower has been lowered. The Packard 1A-1551 engine, which will be installed in our first rigid airship, has completed its test and shows a fuel consumption of 0.44 lb. per b.hp-hr. Of the lighter engines, the test of the Aeromarine U-8-D, an eight-cylinder V-type water-cooled engine, was satisfactory in every respect except in the weight per horsepower. When redesigned, the weight was materially decreased, the output increased and at the same time the durability was maintained, the original model weighing 575 lb. and developing 225 b.hp. at 1800 r.p.m. and the modified engine weighing 520 lb. and developing 260 b.hp. at the same speed. A still lighter model, the Wright E-2, having approximately the same characteristics as the U-8-D and being a development of the small Hispano-Suiza, has undergone satisfactory endurance tests, but several changes are being incorporated into a later model, the E-4.

The cost of overhauling aircraft, he said, is not generally appreciated, the standard Liberty engine requiring 300 man-hours of labor for overhauling after every 72 hr. of flying operation, that is, 4.2 hr. of overhauling labor at a cost of $6.30 for each hour of flying, or approximately 8.4 cents per mile. This does not include the cost of replacement parts.

Recent designs have demonstrated that a reduction of weight is possible without sacrificing either strength or durability; the Wright model T-2 weighs 1150 lb., has a piston-displacement of 1950 cu. in. and a normal output of 550 b.-hp.; the Curtiss model D-12 weighs 670 lb., has 1145-cu. in. piston-displacement and develops 375 b.-hp. at 1800 r.p.m.; and an experimental model now under construction will weigh 1150 lb., have a total piston-displacement of 2450 cu. in. and an assumed output of 775 hp. at 1800 r.p.m. At its rated output of 625 hp. the weight will be 1.80 lb. per hp.; at the designed horsepower it will be 1.55 lb. per hp.

Among the other subjects that have been investigated are the practicability of using larger cylinder-bores, the possibility of increasing the rotative speed and the brake mean effective pressure and the question of realizing a higher specific power and a lower specific fuel-consumption through the use of higher compression-ratios. The test of the Wright Model D-1, a six-cylinder vertical engine with 7-in. bore and 8-in. stroke, has demonstrated its entire suitability for dirigible service; the Wright model T-2 and the Curtiss model D-12 both have been run for hours at a 20-per cent overload without evidence of failure in any part; and the problem of higher compression is said to hinge entirely on the procuring of a fuel that will not only obviate detonation but will be available in large quantities at a reasonable cost. A blend containing 30 parts of alcohol and 70 parts of gasoline appears to meet these conditions.

Because of the large number on hand, although they have been falling behind the procession, the Liberty engines also have been undergoing a process of remodeling with a view to improving their durability, dependability and the weight factor. The predicted performance of the modified types indicates that a marked improvement in all these respects is to be expected.

With regard to the comparative merits of air-cooled and water-coolel engines, it is the opinion of Lieutenant Leighton, based on the results of 2 years of intensive testing, that there is nothing to indicate that the air-cooled engine is less efficient, flexible, powerful, dependable or durable, or more sensitive to changes in altitude or in temperature than the water-cooled engine; on the other hand, it is lighter, requires less preliminary running to warm-up in cold weather and less attention on the part of the pilot in flight, and its installation is distinctly simpler and cheaper. In the preliminary flights and in the early laps of the race at Detroit, two airplanes, identical in every respect except in powerplant, one being equipped with the Wright model E-2 water-cooled engine and the other with the Lawrance model J-1 air-cooled engine, appeared to be exactly equal in speed at the same propeller speed. The water-cooled type did not finish the race on account of a broken propeller tip. In the naval service the air-cooled engine in the smaller sizes, up to 300 hp., has definitely displaced the water-cooled engine. In commercial service, the argument is advanced that the saving of dead-weight by the use of air-cooled engines would increase the possible pay-load without in any way affecting the performance characteristics of the airplane.

Mr. Lewis' talk was illustrated by lantern-slides. After showing the original Wright airplane and describing the early efforts to fly, he contrasted the primitive types with those of the present day and included views of some of the gliders. The methods employed to solve airplane problems by the wind-tunnel were outlined, with special reference to the study of scale effect, and to the investigation of the distribution of forces over the various surfaces of airplanes, an investigation that has led to new methods of control and of construction and to the design of new types of instruments for measuring performance.

Past-President Bachman, Vice-President H. M. Crane, Mr. Van Ness, Mr. Lewis, R. M. Parsons, W. S. James, Lieutenant Leighton and Dr. H. C. Dickinson participated in the discussion.

PRESSURES IN GASEOUS EXPLOSIONS

ON igniting a homogeneous inflammable gaseous mixture contained in a closed vessel, a sphere of flame with the point of ignition as the center spreads outward, slowly at first, and then with increasing speed. As the flame spreads, the potential chemical energy of the combustible gas is transformed into thermal energy, and the temperature and pressure of the burning gas rise in consequence. The pressure rises slowly at first and then rapidly until a maximum rate of pressure rise is attained, which remains constant for some time. Later, the rate of rise becomes less until the maximum pressure is reached, and afterward the pressure begins to decrease owing to the cooling action of the walls of the containing vessel. The period that elapses between the moment at which the pressure begins to rise, and the moment at which the pressure attains its maximum value, is known as the time of explosion.

The greater part of the burning takes place during the explosion period, but a considerable proportion of the gas remains unburnt at the moment of maximum pressure, and the combustion of this unburnt gas takes place as the mixture cools. An appreciable volume of inflammation also appears to take place before the pressure begins to rise, that is, during the period that elapses between the moment of passage of the ignition spark and the moment when the pressure begins to rise. This period has been termed the pre-pressure period.

It was predicted by Sir Dugald Clerk and experimentally confirmed by the late Prof. Bertram Hopkinson that the flame completely filled the explosion vessel some little time before the attainment of the maximum pressure. During the explosion of a 10-per cent mixture of coal-gas and air at atmospheric density in a vessel of 6.20-cu. ft. capacity, for which the time of explosion was 0.25 sec., Hopkinson found that the flame completely filled the vessel about 1/30 sec. before the attainment of the maximum pressure. The maximum pressure developed in this experiment was 82 lb. per sq. in., and the pressure at the moment when the flame completely filled the vessel had risen as high as 70 lb. per sq. in.

A very interesting point, first noticed by Hopkinson, is that the portions of the gas first ignited undergo adiabatic compression, due to an increase of the pressure developed by the later inflammation of the surrounding portions. Owing to this, the distribution of temperature in the gaseous mixture at the moment of maximum pressure is far from being uniform. The gaseous mixture at this moment consists of a hot core surrounded by cooler portions. In one of Hopkinson's experiments with a 10-per cent mixture of coal-gas and air, it was found that, while the mean temperature of the gaseous mixture at the moment of maximum pressure was about 1600 deg. cent. (2912 deg. fahr.), the temperature of the hot core was as much as 1900 deg. cent. (3452 deg. fahr.).

In some experiments made with an optical indicator with a high-frequency spring, when the spark was placed in the center of the vessel, the time of explosion was less and the maximum pressure developed was greater than when the spark was placed near one end of the vessel. In the former case, the time of explosion was 0.050 sec. and the maximum pressure 105 lb. per sq. in. above that of the atmosphere, and in the latter case 0.075 sec. and 100 lb. per sq. in.

Curves were taken with a 15.0-per cent mixture composed of 15 parts of coal-gas and 85 parts of air, with a 12.5-per cent mixture and with a 10.0-per cent mixture. All the gaseous mixtures were at atmospheric pressure before firing. In the strong mixture a maximum pressure of 105 lb. per sq. in. above that of the atmosphere was developed in 0.056 sec.; in the medium mixture, 90 lb. per sq. in. in 0.075 sec.; and in the weak mixture, 76 lb. per sq. in. in 0.140 sec. The 15-per cent mixture required practically the whole of the oxygen in the air for its complete combustion. The weakest mixture of this coal-gas that would ignite on the passage of the spark contained between 7 and 8 per cent of coal-gas.

Similar curves were taken of hydrogen-and-air mixtures of 25.0 per cent, 15.3 per cent and 10.0 per cent. The strong mixture gave a maximum pressure of 87 lb. per sq. in. above atmosphere in 0.014 sec., the medium mixture a maximum pressure of 61 lb. per sq. in. in 0.060 sec., and the weak mixture a maximum pressure of 44 lb. per sq. in. in 0.250 sec.

The time of explosion increases slightly with the density; at ½ atmosphere it is 0.0420 sec., while at 1 atmosphere it is 0.0500 sec., and at 1½ atmospheres 0.0575 sec. The ratio of the maximum absolute-pressure to the initial pressure increases slightly with the density. At ½ atmosphere this ratio is about 7.75, while at densities of 1 atmosphere and over it is a little greater than 8.00. This is due mainly to the relative decrease in the heat-loss during the explosion period as the density is increased.

Sir Joseph Petavel, experimenting with coal-gas and air mixtures at very high densities, also found that the ratio of the maximum to the initial pressure increases with the density. Thus, for a particular mixture at about 75 atmospheres this ratio was about 8.6, whereas for the same mixture at atmospheric density in the same explosion vessel, the ratio was about 7.0.

Effect of Interior Finish

The interior surface of the explosion vessel was silver-plated and could therefore be made either reflecting by polishing or absorbent as regards radiation by blackening. With two identical 15-per cent mixtures of coal-gas and air, but in the one case the walls of the vessel being polished, and in the other case blackened, the maximum pressure was about 3 per cent greater and the rate of cooling much slower with the polished vessel. This is a result first discovered by Hopkinson. The reason for the greater pressure and the slower cooling in the polished vessel is that the radiation emitted by the hot gaseous mixture is reflected back by the walls and reabsorbed by it.

With 25-per cent mixtures of hydrogen and air exploded under similar conditions as the coal-gas mixtures, the rate of cooling in the polished vessel is considerably less than that in the blackened vessel, but the maximum pressure in the polished vessel is not appreciably greater than that in the blackened vessel. This is due to the fact that the amount of radiation emitted during the very short explosion period is very small.

Effect of Inert Carbon Dioxide

In replacing the nitrogen of the air by inert carbon dioxide, a 15-per cent mixture of coal-gas and air composed of 15.0 per cent of coal-gas, 17.8 per cent of oxygen and 67.2 per cent of nitrogen; a mixture containing 15.0 per cent of coal-gas, 26.4 per cent of oxygen, and 58.8 per cent of carbon dioxide; and a mixture containing 15.0 per cent of coal-gas, 19.7 per cent of oxygen and 65.3 per cent of carbon dioxide, the presence of carbon dioxide reduces greatly the maximum pressure developed and slows down the speed of combustion; further, the greater the proportion of carbon dioxide, the lower the pressures and the slower the burning. The lower maximum-pressures produced in the carbon-dioxide mixtures are due in a large measure to the greater volumetric or specific heat of carbon dioxide as compared with that of nitrogen. Probably, too, in the carbon-dioxide mixtures rather less of the coal-gas is burnt at the moment of maximum pressure than in the nitrogen mixtures.—Prof. W. T. David in *Engineering* (London).

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Jan. 10 and Feb. 10, 1923. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ANDO, CHIYO (F M) designer and production manager, Nakashima Aircraft Works, *Ota, Gunmaken, Japan.*

AUSTIN, SAMUEL (A) service manager, Austin Automobile Co., 19 Seyms Street, *Hartford, Conn.*

BAGGS, H. S. (A) president, Norfleet-Baggs, Inc., South Main Street, *Winston-Salem, N. C.*

BAYLESS, RAY T. (M) chemical engineer and metallurgist American Society for Steel Treating, *Cleveland,* (mail) 4600 Prospect Avenue.

BEAL, H. S. (A) assistant general manager, Jones & Lamson Machine Co., *Springfield, Vt.,* (mail) 27 Orchard Street.

BLACKINTON, GEORGE WILSEY (M) works manager, Continental Motors Corporation, *Detroit,* (mail) 160 Grand Boulevard.

BOHLEN, CHARLES (J) draftsman, International Motor Co., *New York City,* (mail) 950 Union Avenue.

BROWN, JAY R. (M) chief engineer, Western Automatic Machine Screw Co., *Elyria, Ohio,* (mail) 246 George Street.

CALLUM, JOHN R. (A) designer and builder of racing cars, J. R. Callum & Co., *Norfolk, Va.,* (mail) 1700 West Ghent Boulevard.

CHILDS, WILL P. (M) manager, Western Screw & Specialty Co., *Racine, Wis.,* (mail) 1508 Main Street.

CORNFORTH, R. GARDNER (J) chief engineer, Nice Ball Bearing Co., *Philadelphia,* (mail) 2047 West Tioga Street.

DE LA VERGNE MACHINE CO. (Aff) Foot of East 138th Street, *New York City.*
Representative:
Doelling, Louis, general manager.

DICK, JAMES B. (A) production engineer, D'Arcy Spring Co., *Kalamazoo, Mich.,* (mail) 810 North Burdick Street.

ELLEMAN, THOMAS H. (A) research engineer, General Motors Research Corporation, *Dayton, Ohio,* (mail) R. F. D. No. 16.

ELLIS, CAPT. CARROLL L. (S M) tank department, *Aberdeen Proving Ground, Md.*

FORBES, MYRON EDSON (A) president, Pierce-Arrow Motor Car Co., *Buffalo, N. Y.*

FORD, E. LOUIS, JR. (E S) student, Yale University, *New Haven, Conn.,* (mail) 38 Hubinger Street.

FORDHAM, THOMAS B. (M) superintendent, Delco-Light Co., *Dayton, Ohio.*

FOSTER, WILLIAM J. (S M) aeronautical mechanical engineer, Air Service, McCook Field, *Dayton, Ohio,* (mail) care E. C. Doren, R. F. D. No. 1, Salem Pike.

GELDS, HARRY (A) instructor in automobile mechanics, El Paso Public Schools, El Paso, Tex., (mail) P. O. Box 40, Lakewood Branch, *Cleveland.*

GOLEMAN, NAHUM (E S) student, University of Michigan, Ann Arbor, Mich., (mail) 320 Belmont Avenue, *Detroit.*

GUBITZ, WERNER (J) Springfield Body Corporation, 1819 Broadway, *New York City.*

GULF REFINING CO. (Aff) Frick Building Annex, *Pittsburgh*
Representatives:
Beatty, C. G., sales department, New York City.
Douglas, S. T., sales department, Boston.
Graham, H. B., chief lubrication engineer.
Hobart, H. P., manager, lubricating department.
Mathis, H. C., sales department, Philadelphia.

HANNUM, G. H. (M) president and general manager, Oakland Motor Car Co., *Pontiac, Mich.*

HAYLETT, R. E. (M) assistant manager, manufacturing department, Union Oil Co. of California, Los Angeles, (mail) Union Oil Co. of Cal., *Wilmington, Cal.*

HECKMAN, J. A. (J) treasurer, Heckman Signal Co., Denver, (mail) 1328 North 17th Street, *St. Louis.*

HERBRAND CO. (Aff) *Fremont, Ohio.*
Representative:
Tyler, R. H.

HERRLIN, KARL O. (E S) student, Lewis Institute, *Chicago,* (mail) 2622 Schubert Avenue.

JACKMAN, CHARLES W. (J) draftsman, Chevrolet Motor Co., *Detroit,* (mail) 1774 Helen Avenue.

JEFFRIES, SCHUYLER A. (M) engineering department, Reo Motor Car Co., *Lansing, Mich.*

JONES, AUGUST F. (E S) student, Cornell University, *Ithaca, N. Y.,* (mail) 519 Stewart Avenue.

KREBS, HENRY (J) turbine engineering department, General Electric Co., *Lynn, Mass.,* (mail) 11 Shepard Street.

LEHMAN, MILTON S. (E S) student, Ohio State University, *Columbus, Ohio,* (mail) 174 East Woodruff Avenue.

LEIGHTON, LIEUT. BRUCE G. (S M) bureau of aeronautics, Navy Department, *City of Washington.*

LYTLE, R. W. (M) assistant chief engineer, Stephens Motor Works of Moline Plow Co., *Freeport, Ill.*

MCQUADE, HARRY W. (M) vice-president and chief engineer, National Pressed Gear Co., *Canton, Ohio,* (mail) P. O. Box 432.

MEYERS, WILLIAM H. (A) draftsman, Nordyke & Marmon Co., *Indianapolis,* (mail) 2202 North Alabama Street.

MOE, ORION G. (J) student, Leland Stanford, Jr., University, *Stanford University, Cal.,* (mail) P. O. Box 855.

OTT, T. F. (M) superintendent of the lubricating division, manufacturing department, Union Oil Co. of California, Los Angeles, (mail) *Oleum, Cal.*

PARCELL, EARL W. (A) designing engineer, Fairbanks, Morse & Co., *Beloit, Wis.,* (mail) 632 Milwaukee Road.

PARKER, LINUS J. (M) designer, H. H. Franklin Mfg. Co. *Syracuse, N. Y.,* (mail) 314 Delaware Street.

PEASE, FRANK D. (J) laboratory engineer, Studebaker Corporation, *Detroit,* (mail) 2486 LaMathe Avenue.

PLACE, REUBEN MEREDITH (A) branch manager, Ahlberg Bearing Co., Chicago, (mail) 142 Tenth Street, *Toledo.*

PORTER, ROLLAND C. (J) designer, Prudden plant, Motor Wheel Corporation, *Lansing, Mich.,* (mail) 717 West Michigan Avenue.

PRESTON, L. H. (A) Ansted Engineering Co., *Connersville, Ind.*

RENOLD, INC., HANS (Aff) 365 Broadway, *New York City.*
Representatives:
George, H., vice-president.
Joy, J., engineer.
Mills, E. W., treasurer.

ROCCHETTI, JOSEPH (M) chief engineer, Manitoba Power Commission, *Winnipeg, Man., Canada.*

SANFORD, ROY S. (A) inventor, Sanford Fore-Wheel Brake Co., *Pasadena, Cal.,* (mail) 20 South Vernon Avenue.

SCHNEPEL, HERBERT (J) layout draftsman, Nordyke & Marmon Co., *Indianapolis,* (mail) 250 Oxford Street.

SHOEMAKER, FRED R. (E S) student, University of Illinois, Urbana, Ill., (mail) 406 East Healy Street, *Champaign, Ill.*

SKURRAY, ERNEST C. (A) engineer, Skurray's, *Swinton, Wiltshire, England.*

SLOCOMBE, W. VERNON (A) assistant engineer in charge of production, Turbulator Corporation, *Chicago,* (mail) 2711 North Kedzie Avenue.

THORSON, WILBUR R. (J) assistant manager, Central Iowa Electric Co., McCallsburg, Iowa, (mail) P. O. Box 452, Station A, *Ames, Iowa.*

TODD, FILLMORE W. (A) president, Accessories Mfg. Co., 2311 North Crawford Avenue, *Chicago.*

TREVELYAN, HARRY A. (M) assistant superintendent of inspection, Studebaker Corporation of America, *Detroit,* (mail) 5038 Crane Avenue.

USHIODA, SEIKICHI (E S) student, Cornell University, *Ithaca, N. Y.,* (mail) 201 Bryant Avenue.

VIDALIE, RENE M. (M) designer and engineer, Doble Steam Motors, *San Francisco,* (mail) 1055 Washington Street.

WALLACE, DONALD E. (A) experimental engineer, Shakespeare Co., *Kalamazoo, Mich.,* (mail) 810 Davis Street.

WARNER, W. M. (A) manager, parts department, Cadillac Motor Car Co., *Detroit.*

WELCH, STANLEY P. (A) 509 Monroe Avenue, *Elizabeth, N. J.*

WHITE, KARL H. (J) aeronautical engineer, Aeromarine Plane & Motor Co., *Keyport, N. J.,* (mail) 162 Church Street.

WHITEHEAD, J. FRAZER (A) secretary and treasurer, Kales Stamping Co., 1657 West Lafayette Boulevard, *Detroit.*

WILLIAMS, EMERSON MARION (E S) student, University of Michigan, *Ann Arbor, Mich.,* (mail) 719 Church Street.

WOLLERING, MAX F. (M) vice-president, Studebaker Corporation of America, *Detroit,* (mail) 36 McLean Street.

YACKEY, HAROLD HILGARD (E S) student, University of Illinois, *Urbana, Ill.,* (mail) 1003 West Nevada Street.

Applicants *for* Membership

The applications for membership received between Jan. 15 and Feb. 15, 1923, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, CHARLES S., student, New York University, *New York City.*

ALEXANDER, DONALD, Edward G. Budd Mfg. Co., *Philadelphia.*

BAIN, GERALD, *Haynesville, La.*

BALLENTINE, WILLIAM I., vice-president, Advance-Rumely Co., *La Porte, Ind.*

BANES, WILLIAM K., carbureter expert, U. S. Industrial Alcohol Co., *Baltimore.*

BENÉT, LAURENCE V., vice-president, Hotchkiss & Cie., *St. Denis (Seine) France.*

BERKOWITZ, IRVING H., engineer, Diamond Taxi-Cab Co., *New York City.*

BLOSSOM, ROY E., special sales representative, Prest-O-Lite Co., Inc., *Indianapolis.*

BOWMAN, JOHN ALDEN, comptroller, John W. Brown Mfg. Co., *Columbus, Ohio.*

BUNNELL, FRED H., student, Michigan Agricultural College, *East Lansing, Mich.*

CAMPBELL, FRED J., chief draftsman, Falls Motors Corporation, *Sheboygan Falls, Wis.*

CATLIN, AUREL A., student, Michigan Agricultural College, *East Lansing, Mich.*

CLEMENS, FRED J., mechanical superintendent, Robert Mfg. Co., *New Haven, Conn.*

COLLINS, P. A., technical service department, Reo Motor Car Co., *Lansing, Mich.*

COOK, WALTER, student, Michigan Agricultural College, *East Lansing, Mich.*

CROWE, G. FRANCIS, student, University of Toronto, *Toronto, Ont., Canada.*

CRUDEN, J. P., district sales manager, Standard Oil Co., *Walla Walla, Wash.*

DAVIE, ARTHUR J., student, Michigan Agricultural College, *East Lansing, Mich.*

DEGENER, PAUL A., president, Rochester Motors Corporation, *New York City.*

DONNER STEELE CO., INC., *Buffalo, N. Y.*

DOWNEY, J. S., salesman, Chanslor & Lyon Co., *Los Angeles.*

DRAKE, HAROLD, airplane designer, G. Elias & Bro., *Buffalo.*

DRUMM, EDGAR A., principal of Y. M. C. A. automobile school, *City of Washington.*

DUNBAUGH, GEORGE J., JR., secretary, Champion Mfg. Co., *Chicago.*

ESKOWIT, ISADORE, student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

FAIRBANK, CHARLES WILLIAM, test engineer, Standard Oil Co. of New Jersey, *Baltimore.*

FALCONER, JOHN WILLARD, student, Armour Institute of Technology, *Chicago.*

FRANCIS, PHILIP W., Yorktown Motor Co., *Yorktown Heights, N. Y.*

FRANCIS, TENCH, Yorktown Motor Co., *Yorktown Heights, N. Y.*

GLEISEN, D., manager, Eastern division, Hyatt Roller Bearing Co., *New York City.*

GRATWICKE, WALTER, engineer, British Aluminum Co., Ltd., *New York City.*

GREENE, WHITNEY E., instructor, Pennsylvania State College, *State College, Pa.*

HACKETT, FRANK J., service manager, Sills-Chevrolet Co., *Boston.*

HACKHAM, GEORGE JOHN, chief engineer, Yellow Coach Mfg. Co., *Chicago.*

HAIGH, JAMES H., student, Michigan Agricultural College, *East Lansing, Mich.*

HANNING, JAMES ROWLAND, student, University of Toronto, *Toronto, Ont., Canada.*

HARTSHORN, STANLEY DENTON, student, Massachusetts Institute of Technology, *Cambridge, Mass.*

HAPPERSETT, ROLAND H., student, Tri-State College, *Angola, Ind.*

HIGGINS, WILLIAM H. C., chief engineer, Advance-Rumely Co., *LaPorte, Ind.*

HOFFMAN, E. E., chief engineer, Hendee Mfg. Co., *Springfield, Mass.*

HOLMES, LAWRENCE J., factory manager, International Motor Co., *Allentown, Pa.*

HUGHES, LLOYD I., student, Michigan Agricultural College, *East Lansing, Mich.*

INGERSOL, AUSTIN O., student, Michigan Agricultural College, *East Lansing, Mich.*

JACKSON, LEE R., district manager, Firestone Tire & Rubber Co., *Detroit.*

JAYCOX, RANDALL EUGENE, automobile repairman, Oak Ridge Oil Co., *Santa Paula, Cal.*

JUDSON, ARTHUR, vice-president, Fuller & Smith, *Cleveland.*

KELLER, A., vice-president and works manager, Golde-Patent Mfg. Co., *New York City.*

KINNEY, ALDON M., assistant superintendent, Cropper-Kinney Auto Spring Co., *Lebanon, Ohio.*

KLINGER, G. W., engineer of tests, and manager of automotive department, Vibration Specialty Co., *Philadelphia.*

LEAVER, ALBERT JOSEPH, consulting automotive engineer, *Brisbane, Queensland, Australia.*

LEROY, B. L., engineer, Beans Spring Co., *Massillon, Ohio.*

LEWIS, WERNER H., student, Michigan Agricultural College, *East Lansing, Mich.*

LITTLE, J. GRIFFIN, student, Michigan Agricultural College, *East Lansing, Mich.*

LOGAN, G. L., technical service department, Packard Motor Car Co., *Detroit.*

LUCKETT, DINWIDDIE J., ordnance engineer, design section, Ordnance Department, *Rock Island Arsenal, Ill.*

MCADAM, D. J., JR., metallurgist, Naval Engineering Experiment Station, *Annapolis, Md.*

MACDONALD, W. W., chief engineer, MacDonald Truck Division, Union Construction Co., *Oakland, Cal.*

MACK, WILLIAM, sales manager, Borg & Beck Co., *Chicago.*

MARKEY, ROSCOE I., aeronautic designer, engineering division, Air Service, McCook Field, *Dayton, Ohio.*

MAXIM, ALBERT, engineering mechanic, Ward Motor Vehicle Co., *Mount Vernon, N. Y.*

MEIGS, DWIGHT R., vice-president, U. S. Axle Co., *Pottstown, Pa.*

MEYER, ALVIN W., mechanic, Waddams Garage, *Waddams Grove, Ill.*

MORRISH, NEIL B., student, Michigan Agricultural College, *East Lansing, Mich.*

MORRISON, EARL L., student, Michigan Agricultural College, *East Lansing, Mich.*

OTTENHOFF, W. B., manager of engineering and service division, Indian Refining Co., Inc., *New York City.*

PEASLEE, W. D. A. chief engineer, Belden Mfg. Co., *Chicago.*

PFEIFFER, ARTHUR E., student, University of Illinois, *Urbana, Ill.*

PLATZ, HENRY A., student, Michigan Agricultural College, *East Lansing, Mich.*

POKORNY, FRANK, experimental engineer and president, Rex Motor Control, *Mamaroneck, N. Y.*

PORTER, H. K., directing engineer, Eastern division, Hyatt Roller Bearing Co., *New York City.*

PRESBREY, OTIS FLAGG, instructor, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

RABIDOUX, EDWARD J., service supervisor, Reo Motor Car Co. of New York, *New York City.*

REED, NEWTON L., superintendent of motor equipment, Crew Levick Co., *Philadelphia.*

ROBB, WILLIAM C., assistant manager, Ohio Rubber Co., *Detroit.*

SCHWEITZER, PAUL H., mechanical engineer and tool designer, Oakland Motor Car Co., *Pontiac, Mich.*

SHERWOOD, H. H., president, Sherwood Petroleum Co., Inc., *Brooklyn, N. Y.*

SLAKER, CHARLES S., general manager, Hayes Wheel Co., *Jackson, Mich.*

SLATTERY, MICHAEL W., instructor, Arsenal Technical Schools, *Indianapolis.*

SMALL, FRED FULTON, mechanical superintendent, Pacific Electric Railway Co., *Los Angeles.*

SOHLINGER, W. J., vice-president and general manager, Flint Varnish & Color Works, *Flint, Mich.*

SPENCER, ROBERT D., student, Michigan Agricultural College, *East Lansing, Mich.*

SPERLING, EZRA F., student, Michigan Agricultural College, *East Lansing, Mich.*

STIFF, MASON C., student, Michigan Agricultural College, *East Lansing, Mich.*

STILGER, WILLIAM M., parts manager, Hudson Motor Co. of Illinois, *Chicago.*

TELFORD, MARSHALL H., student, Tri-State College, *Angola, Ind.*

THOMSON, WILLIAM G., automobile mechanic, Consumers Ice Co., *San Francisco.*

TRANSCONTINENTAL OIL CO., *Pittsburgh.*

TRUSCOTT, PERCY JOHN, student, Michigan Agricultural College, *East Lansing, Mich.*

WACHTLER, WILLIAM B., directing engineer, Hyatt Roller Bearing Co., *Newark, N. J.*

WADIA, J. R., automobile engineer, c/o Mathews & Co., *Bombay, India.*

WATANABE, TORAJIRO, professor, College of Engineering, Waseda University, *Tokyo, Japan.*

WELSH, JAMES W., executive secretary, American Electric Railway Association, *New York City.*

WHARAM, JOHN H., assistant engineer, Lincoln Motor Co., *Dearborn Mich.*

WILD, MARK, works manager, Meteor Works, Rover Co., Ltd., *Coventry, England.*

WILLIAMS, FRANCIS, sales manager, Gardner Waern & Co., Ltd., *Melbourne, Victoria, Australia.*

WRIGHT, J. R., research engineer, Standard Oil Co. of New Jersey, *Elizabeth, N. J.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

Painting Troubles

ONE of the most general manufacturing problems encountered of late has been that epitomized as paint-trouble. The Detroit Section devoted its March meeting to this subject and the wide-spread interest in it is reflected in the attendance which exceeded 250. A feature of the meeting was the rapid-fire answering of practical questions by the speaker, L. V. Pulsifer. These questions with the answers form a valuable paper on painting that is recommended to the members for careful reading. The report will be found on p. 335.

Farm Tractor Meeting

THE Society will hold its annual Tractor Meeting at the Auditorium Hotel, Chicago, April 19. Engineering sessions have been scheduled in the morning and afternoon with an informal Tractor Luncheon at noon. One technical paper will be read at each of the sessions. The all-purpose type of farm tractor will be the subject discussed in the morning session. Constructive engineering criticism based on the Nebraska tractor tests will be presented in the afternoon. Both papers will have a distinct bearing upon the design of the farm tractor of the future. Further details of this meeting are given on p. 398.

Automotive Traffic

OUR trucks move 1,250,000,000 tons of freight a year. Allowing for 10,000,000 passenger cars in daily use, on the basis of 2½ persons riding in a car, we have 25,000,000 automobile passengers daily. Seventy-two per cent of all the automobiles go into population points of 50,000 or less, 52 per cent into points of 10,000 or less and 30 per cent into points of 5000 or iess.

We have $1,500,000,000 invested in our plants. We produce more than 2,000,000 units of transportation yearly. The wholesale value of cars, trucks, tires and accessories, in 12 months, amounts to $3,500,000,000. We expend for material $1,250,000,000. We pay $350,000,000 of wages to 250,000 factory employes, and open a means of livelihood to perhaps as many more associated with dealer plants, garages, repair shops and filling stations.—George M. Graham.

Automotive Transportation Meeting

A NATIONAL meeting of the Society will be featured this month devoted entirely to the topic of automotive transportation. It is scheduled in Cleveland, April 26 to 28, and will include several professional meetings, the Motor Transport Dinner and a group of factory visits. The attractive program of papers printed on p. 399 reflects the scope and importance of this meeting. Some of the Country's ablest transport authorities will read their opinions on automotive-transportation problems. The motor truck, motorbus and taxicab will each receive attention. The meeting is of primary importance to everyone in the automotive-transport business be he engineer, vehicle builder or operator. Reduced railroad fares and the central location of the meeting place render attendance inexpensive and convenient.

S. P. A. E.

HARTLEY MANNERS, in a fit of irritation, has called our theatrical managers glorified janitors. How can glory be added to him in whose person all known glories, splendors and powers are already centralized? What Mr. Manners really meant was that the managers are half-hearted janitors, with the inferiority complex, who perform the work of a janitor but dare not assume the name and regalia.

That reproach cannot be brought against the members of the Society of Professional Auto Engineers. There is a Society of Automotive Engineers, composed not of amateurs as might be hastily inferred, but of engineers engaged in the production of automotive vehicles. But the Society of Professional Auto Engineers is composed of persons who operate automotive vehicles. The coarse unfeeling world has been calling them chauffeurs. "Chauffeur" means the man who heats up, and the Professional Auto Engineers heat up only when you call them chauffeurs. They want to eliminate that disgusting word, not only for themselves but for humbler brethren in similar occupation, who are hereafter to be known as automobile drivers.

Not every automobile driver, it appears, can get into the Society of Professional Auto Engineers. That is confined to "professional operators of automobiles in

private employment." A taxi driver is not a professional automobile engineer. Yet even he is above being stigmatized by the epithet of chauffeur, it seems, and the Society of Professional Auto Engineers wants us all to get into the habit of using the term "automobile driver" for persons who operate taxis and trucks. But for professionals in private employment the term engineer is reserved, thus maintaining the heaven-born distinctions of the caste system on the driver's seat. All that is now needed is a simple terminology to describe the three ranks of passengers; those who own a car driven by a Professional Auto Engineer, those who own and drive their own, and those who own nothing but the price of a taxi ride.

Luckily we have the three terms ready to hand. They come down from old times, with some antique connotations, but their substantial meaning suits the need, nobles, gentry and the common herd.—*New York Times.*

1923 Roster

THE 1923 Roster of the Society will be mailed early in April to those members who ordered copies of it prior to March 15, in accordance with the notice that was sent to all members in December. A small surplus supply has been provided for stock and members who order late will be supplied until the stock has been exhausted, but no reprint of the Roster will be made to supply all those whose orders were received after March 15.

Because of the number of changes of address and company affiliation that are constantly occurring in the roster files of the Society, special care has been taken to obtain the most uptodate information possible and to print the roster as quickly as possible after a specific closing date. Changes in address have been made up to the time of receipt of final page-proofs. Four change-of-address blanks were sent to the entire membership between Oct. 1 and March 15. Approximately 4000 members replied, necessitating 2500 corrections in the files.

To eliminate clerical errors so far as possible and to speed up the work of printing, the writing of copy is eliminated by maintaining a special file of cards for the Roster, which is kept uptodate and furnished to the printer as copy when the Roster is to be printed. This has eliminated 2 months' work of 5 typists and reduced the time consumed in printing the Roster from 4 months to 30 days. This, we believe, gives the members a Roster as nearly uptodate as is physically possible in an organization of the size of the Society.

The book is divided into three main classifications; the alphabetical register, the company list and the geographical register of members. In addition the book contains tables giving the residence of the members by States and the number of members of various grades; charts showing the relative increase in the membership and the distribution of the Society's expenditures; lists of the Society Officers and Councilors, the staff, administrative committees, members of the Standards Committee and its Divisions, Past-Presidents, Society representatives in other organizations, officers of local Sections, Society emblems and publications with prices, and information regarding membership and sections.

In connection with the table showing the geographical distribution of members it is interesting to note that New York State holds the greatest number of members of any single State, although the bulk of the membership is located in the Middle West.

Licensing of Engineers

ACCORDING to documentary information available at the headquarters of the Federated American Engineering Societies, as of Oct. 1, 1922, 23 States of the Union had enacted laws requiring the registration of engineers. The provisions of the various laws differ in some major as well as minor respects, such as the type of engineer and the nature of the engineering work covered, and the time of putting penalties into effect, but all of them are understood to be based upon or the result of a bill promulgated generally by the American Association of Engineers. In the States that require registration of "professional engineers" in general the original and renewal license fees range from $1 to $25.

The following States, in which there are important centers of automotive engineering, have such laws applying to "engineers" and "professional engineers": Indiana, Iowa, Michigan, Minnesota, New Jersey, New York, Pennsylvania and Wisconsin. In addition, there are similar laws in Colorado, North Carolina, Oregon, Tennessee, Virginia, and some other States. The penalties under the various laws have been in effect for some time, except in the case of those of New York and New Jersey, which go into effect next month (May 5) and this month (April 8) respectively. No information is at hand regarding prosecution, litigation or judicial decision under the laws, except an indefinite report as to a suit by an engineer to require a State Board to license him. The stipulated penalties for unlicensed practice range from those for misdemeanor to a $500 fine, or imprisonment, or both.

In general, the professional qualifications for licensing are from 4 to 6-yr. experience, with allowance of from 2 to 4 yr. for education of an accepted grade. Employes of registered engineers are exempt in Colorado, Iowa, New York, Oregon, Pennsylvania and Wisconsin. It is stated that in Michigan the law applies to "consultants"; employes of railroads and other "interstate" corporations are exempt. In some of the States "professional engineering" is defined as the practice of any branch of the profession other than military engineering. The New York law reads:

> A person practices professional engineering * * * who holds himself out as able to do the work that an engineer does in the planning, designing, constructing, inspecting and supervising of engineering work, or appliances involved in public or private projects, or in making investigations for proposed engineering projects.

One of the problems of the administration of the laws is the matter of honoring in one State a certificate of license issued to an engineer in another State, by reciprocal arrangement. In the form of agreement of the Council of State Boards of Engineering Examiners it is stipulated that professional experience shall be considered as beginning when the candidate has entered upon a position in professional engineering work that requires individual thought and responsibility; also, that the applicant shall have had 10 yr. of experience in professional engineering and show that he is qualified to design as well as to direct engineering operations, as evidence of qualification for reciprocal registration, and his experience record shall show progressive advancement in the character of the work performed; in addition, that graduation from an engineering school of recognized standing shall be accepted as the equivalent of 4 yr. of such practice.

Recent Developments in Aircraft Engines in the Navy

By Lieut. B. G. Leighton[1], U.S.N.

Washington Section Paper *Illustrated with* Photographs and Drawings

THAT the air-cooled engine in the smaller sizes has definitely arrived and has displaced the water-cooled type in all sizes under 300 hp. in the Naval service is the principal conclusion drawn by the author who also makes the predictions that the air-cooled engine will gradually widen its field of usefulness and displace the water-cooled engine entirely and that the chief hope for bettering aircraft engines lies in perfecting the kind of apparatus that engineers have been accustomed to rather than making any radical departures. These conclusions are reached after an exhaustive discussion of the trend of the successive improvements in engines that have increased the safety, the durability, the dependability and the economy of aircraft. The standard of excellence has been raised from the original 50-hr. test, which consisted of a series of 5-hr. runs, to the present requirement of 300 hr. of continuous running with wide-open throttle at sea-level that represents approximately 600 hr. of normal flying-service and at a speed of 75 m.p.h. would be the equivalent of 45,000 miles of cruising.

The progress made by the Navy Department in reducing the maintenance cost, decreasing the weight per brake horsepower and per cubic inch of piston-displacement and lowering the fuel consumption per brake horsepower by successively redesigning the parts that had failed is outlined, the advances being illustrated by a series of drawings. The possibility of reducing the weight of an engine without sacrificing either strength or durability, as demonstrated in recent designs is emphasized, the text being supplemented by a series of drawings showing the outlines of the engines as compared with the standard Liberty engine and the piston-displacement, the normal power output, the weight per brake horsepower and the piston-displacement per brake horsepower. The Liberty engines have also been undergoing a process of remodeling that has for its object improving their durability and dependability and the weight factor. The predicted performance of the modified types indicates that a marked improvement in all these respects can be expected.

DEVELOPMENT in aircraft construction and operation is limited by two considerations, (*a*) the amount of funds appropriated to the Services by the Federal Government, and (*b*) the effectiveness with which the funds appropriated are expended. I shall attempt to outline the development work that has been done in the particular field of powerplant development with the funds that have been appropriated specifically to the Navy. The scope of the work has been so broad and the details so manifold and varied that time does not permit more than a broad outline of the more important work that has been completed or is in hand. I shall confine myself to the engine itself, and dismiss the subject of accessories, fuel systems, cooling systems and the like, important as they are, with the bare statement that development in these particulars has kept pace with the engines.

In classing this development work as work done "in the Navy" or "by the Navy," I refer to work done under Navy supervision and control, and paid for principally from Naval appropriations. A very great portion indeed of the details of development has actually been executed in private engineering organizations with funds that the Navy has allocated from its appropriations for the particular purpose in view. The Navy's policy has been at all times to handle development projects wherever practicable through the medium of contracts with private engineering organizations, under conditions that assure a reasonable profit to the contractor, to the end that these private engineering organizations may be kept alive and in a healthy condition as the nucleus for the strong well organized commercial aircraft industry that is so vital to the National defense. Without the splendid ingenuity, genius, and resource that have been displayed by the various organizations that have been employed in this work, the results that have been obtained could not have been possible.

It is impracticable to name the various organizations that have been employed in this work, for obvious reasons. Suffice it to say that the Navy has called freely and fully for advice and counsel upon the magnificently organized engineering societies of the country and upon the various Government bureaus and agencies engaged in pertinent lines of work, and has at all times availed itself of the invaluable experience and resources of various private engineering and manufacturing organizations engaged in all manner of engineering work. It has everywhere met with most cordial cooperation and hearty assistance, for which acknowledgment is gratefully made.

Fundamentally, success in aircraft operation, whether it be commercial or military, is largely, one might say almost entirely, dependent upon two vital factors; (*a*) dependability and safety, and (*b*) low operating cost per ton-mile of pay-load carried. Safety and dependability can be had, of course, without low operating cost, but certainly low operating cost cannot be had without safety and dependability. Probably the greatest contributing factor to the present high cost of aircraft operations is the enormous overhead expense incurred by the necessity for frequent and costly repairs and replacements, and by the necessity for constant and most meticulous attention to details. The question of operating cost is perhaps of slightly less moment in military than in commercial operations, but just as high operating costs are today standing in the way of the establishment of the thriving commercial aircraft industry that is so vital to our national defense, so are high operating costs most seriously retarding the full realization to our Army and Navy of the tremendous inherent possibilities in aircraft as a weapon for offense and defense.

[1] In charge of aeronautic engine development, Navy Department, City of Washington.

That our National defense sorely needs a strong self-supporting commercial aircraft industry, goes without saying. The question is, how to create such an industry. And the obvious answer is, let it once be fully demonstrated that aircraft are safe, that they are thoroughly dependable, and that the cost per mile per ton of pay-load carried is comparable to that of other commercial carriers; let these things be clearly demonstrated and there will be no need of worrying about the creation of a commercial aircraft industry; it will create itself.

These factors are properly the first concern of the naval and military aircraft services of our Country, and it is largely in this light that we should view the development work that has been done and is still to be done. Dependability and reasonable durability must come first and always. With thorough dependability comes safety, and a material reduction in maintenance costs. Next in importance to dependability and durability comes the reduction in aircraft weights, because every pound that can be saved in the structure of the aircraft results in a corresponding increase in the pay-load or in the speed and a decrease in the carrying cost.

Former and Present Tests

Generally speaking, an aircraft is only so good as the powerplant that sustains and propels it. Any advance in the performance of the aircraft as a whole can proceed but little faster than the advance in the performance of the powerplant. The two are inseparable. Excellence in performance is purely a comparative factor, and can be visualized only by a reference to some fairly definitely fixed standard of measurement. The standard against which we have in the past measured the excellence of aircraft engines has been the so-called standard 50-hr. test which, stated briefly, requires little more than that an engine shall complete 10 runs each of 5-hr. duration at between 90 and 100 per cent of its rated output without failure in any "major" part, and without "*persistent*" failure in minor parts.

Practically all types of engines in common use today have satisfactorily met the requirements of our 50-hr. test standard, and yet it is a fact that failures of engines and engine accessories have been responsible for more uncompleted flights, forced landings and accidents than all other causes combined. The requirements of the accepted test specifications have been met, but apparently the requirements of actual flight service have *not* been met. It follows, then, that the 50-hr. test as a standard of acceptance must be inadequate. Safety, dependability and economy all demand something far better.

Something over a year ago, the Bureau of Aeronautics of the Navy Department, set up tentatively as a mark to shoot at, a new standard of service acceptability, a test that aimed at demonstrating the entire capability of engines to give continuing dependable service without the necessity for overhaul or other than minor repairs or adjustments for at least as long a period as one might reasonably expect the structure of an airplane to stand up without a thorough going over in normal flight service. The test as originally outlined required three 100-hr. periods of continuous running. Each 100-hr. period comprised 86 hr. at an output corresponding to normal cruising power at 2500-ft. altitude and 14 hr. at wide-open throttle at sea level, to simulate the conditions that obtain in the take-off and the initial climb. This was a long step ahead of the old standard 50-hr. test requirement, and it must be confessed that when we first set up the new standard we were actuated very much more by a determined hope than by confident expectancy. A year's intensive work on a number of types of engine has fully convinced us, however, that this measure of excellence is capable of being fully realized in all classes of engine, without in any way increasing the weight, and we have recently raised the standard to 300 hr. of continuous wide-open throttle running at sea level.

It should be fully realized that wide-open throttle running at sea level taxes an engine far more than does the kind of running that it gets in the hands of an experienced pilot in normal flight service. Actual comparisons made between the conditions noted in identical engines after full-throttle sea-level running and after normal flight operation indicate clearly that the life of an engine in normal flying service is at least double the life of the same engine under full-throttle sea-level running. On this basis, which our experience indicates to be entirely safe, a 300-hr. wide-open throttle test at sea level is the equivalent of at least 600 hr. of operation in normal flying service. At an average cruising speed of 75 m.p.h., this represents some 45,000 miles of cruising. Few airplanes have yet been built whose structures will stand up for this amount of cruising without very complete and extensive overhaul, if at all. I mention these things to indicate that the goal we are aiming at is far above the present general measure of acceptability.

Progress Made in Development

As an example of the type of work that has been done, I shall cite several specific instances. An engine of the model that is being installed in our first rigid airship, the Packard 1A-1551 shown in Fig. 1, has already completed 300 hr. of practically continuous running, developing the maximum output that it will be called upon to develop in flight service. No repairs or refitting of the parts were made throughout the entire test and at the end of the test a careful inspection proved the engine to be still in excellent running condition and in need of no repairs or adjustments. As an indication of the excellent valve conditions that obtained, the average fuel-consumption of this engine for the whole 300 hr. of running was slightly less than 0.44 lb. per b. hp-hr. In fairness to other models of aircraft engines, it should be pointed out that this engine was especially designed for airship service and is very much heavier than the engines used in other classes of service.

In the lighter types of engine that are more particularly adaptable to heavier-than-air service, we have completed a 300-hr. test in three 100-hr. periods[a] with the Aeromarine U-8-D, an eight-cylinder V-type water-cooled engine. During this test the engine was run at part throttle at 1800 r.p.m. developing an output equal to its normal cruising power at a 2500-ft. altitude for a total of 258 hr. and at wide-open throttle at sea level for 42 hr. At the end of the 292nd hr. of the test, a break occurred in the crankshaft, which required the installation of a new shaft to complete the run. This break was serious, of course, but was of such a nature that the cause was very evident and the remedy comparatively simple. Aside from this failure, and a slight retouching of part of the intake-valves at the end of the first 100 hr., no adjustments or repairs were made to the engine throughout the test. At the end of the test the power output of the engine was slightly greater than at the beginning, the valves and their seats, the bearings, the gears and in fact all parts were in excellent condition and in need of no repairs or refitting. This was an extremely gratifying performance from the standpoint of durability and a distinct encouragement, but the engine as tested compared unfavorably in weight

per horsepower and in installation dimensions with another engine of approximately the same power that had been in wide service use.[2] We accordingly set about having changes made in the design not only to decrease its weight materially, but at the same time to increase its output materially, keeping still the same excellent durability characteristics. The redesign, which is designated as the U-873, was completed and subjected to preliminary tests at the increased output. Certain difficulties were encountered that entailed a slight further redesign in certain parts to maintain the all-around durability characteristics desired. The engine is now finally completed, has satisfactorily undergone its preliminary trials and is about to be subjected to its final endurance test, comprising 300 hr. of continuous full-power run-

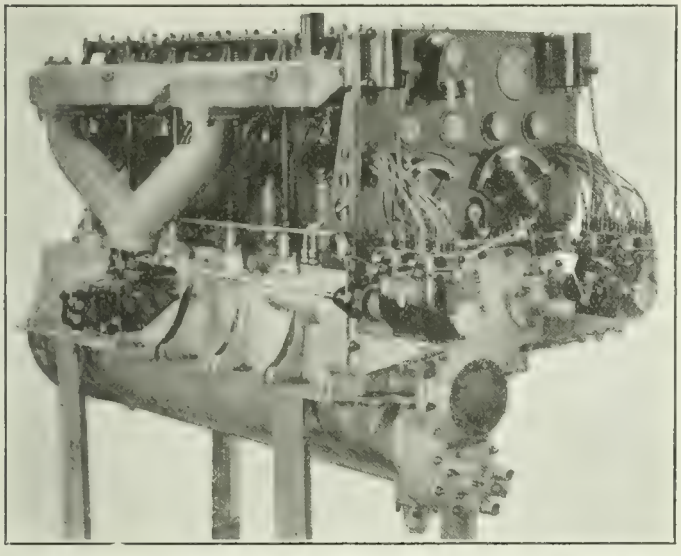

FIG. 1—ENGINE DEVELOPED BY THE PACKARD MOTOR CAR CO. FOR INSTALLATION IN THE NAVY'S FIRST RIGID AIRSHIP

ning. All indications are that this test will be satisfactorily completed. The original model of this engine, the U-8-D, weighed 575 lb. and developed 225 b. hp. at 1800 r.p.m. The modified engine now under test, the U-873, weighs 520 lb. and develops 260 b. hp. at 1800 r.p.m.

Another, and materially lighter model, the Wright Model E-2, having approximately the same general characteristics as the U-8-D was submitted to the same test. This model, which is a development of the small Hispano-Suiza, has been used extensively in our service for advanced training airplanes with very good results by comparison with other engines previously in general use. Our records show that its flying life between overhauls averages 101 hr., as against 72 hr. for the Liberty engine, It had repeatedly been subjected to standard 50-hr. tests and was thought to be an exceptionally durable type, but when we commenced long-duration testing unexpected shortcomings were uncovered, principally in the connecting-rod bearings, the valves and the valve-seats, all of which went bad before the first 100 hr. had been completed. The subsequent development work on this engine is particularly interesting because the results obtained have so completely justified our adoption of the 300-hr. test standard in place of the old 50-hr. standard.

Figs. 2 and 3 show the progress that has been made. Referring to Fig. 2 the graph marked 1, is a graph of the first attempt at a 300-hr. run. Note that in the 14-hr. full-throttle running at the end of the period the

[2] For a specific example of the importance of low weights, see the Appendix.

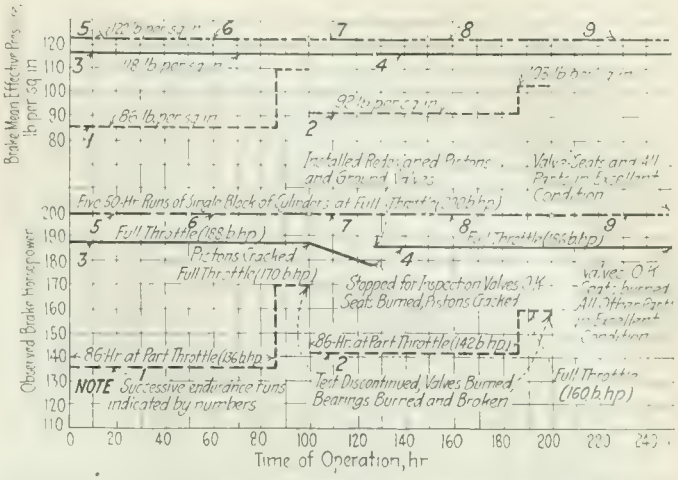
Brake Mean Effective Pressure, lb per sq in
Observed Brake Horsepower
Time of Operation, hr
Five 50-Hr Runs of Single Block of Cylinders at Full Throttle (200 b hp)
Installed Redesigned Pistons and Ground Valves
Valve-Seats and All Parts in Excellent Condition
Full Throttle (188 b hp)
Pistons Cracked
Full Throttle (170 b hp)
Stopped for Inspection Valves, Seat Burned, Pistons Cracked
Valves, Seat Burned, All Other Parts in Excellent Condition
86-Hr at Part Throttle (156 b hp)
86-Hr at Part Throttle (142 b hp)
NOTE Successive endurance runs indicated by numbers
Test Discontinued, Valves Burned, Bearings Burned and Broken
Full Throttle (160 b hp)

FIG. 2 CHART SHOWING THE RESULTS OF PROGRESSIVE DEVELOPMENT ON ONE TYPE OF ENGINE DURING 1 YR.

power output was considerably below the normal rated power of this model, 180 b. hp. at 1800 r.p.m. This condition was brought about by the poor valve conditions. After this run new connecting-rod bearings and valves of the original design were fitted, the valve-seats were reamed out and the valves readjusted, and a second attempt was made as a check on the first, with the result shown in the graph numbered 2. After some investigation and experimentation, new valves and bearings were developed and were fitted in a new engine of the same model. This engine was then set up and subjected to a practically non-stop run of 125 hr. at wide-open throttle as shown in the graph marked 3. An examination at the end of this test showed no evidence of bearing failure and that the valve burning had been corrected completely, but that the valve-seats were seriously eroded. The valves were reseated and adjusted and new pistons

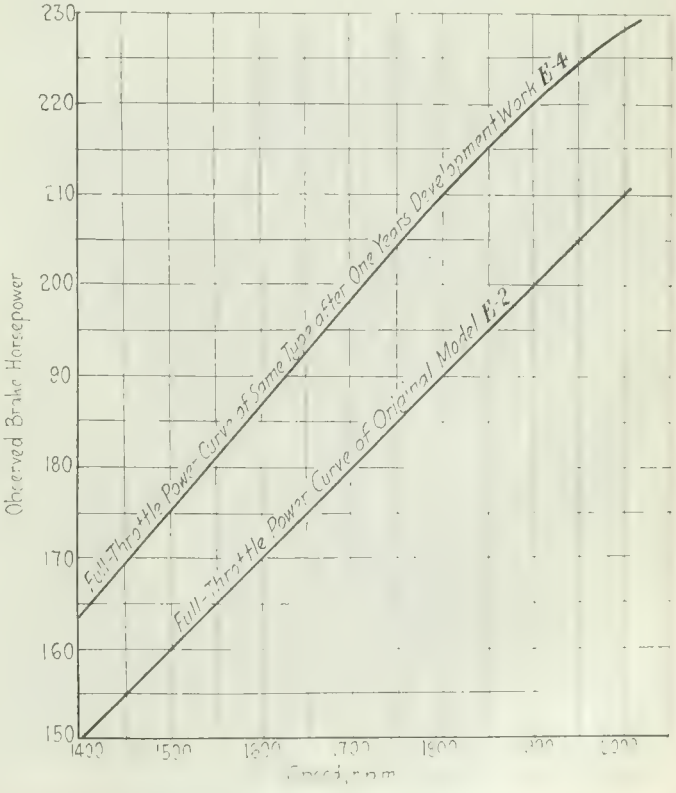
Observed Brake Horsepower
Full-Throttle Power Curve of Same Type after One Years Development Work E-4
Full-Throttle Power Curve of Original Model E-2

FIG. 3—COMPARISON OF THE POWER DEVELOPED BY THE E-2 AND E-4 ENGINES

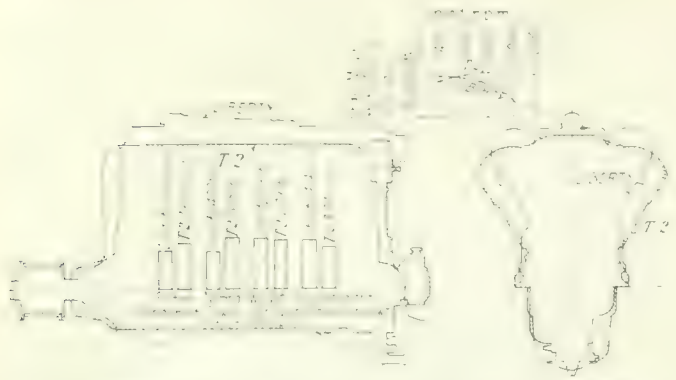

FIG. 4—COMPARISON OF THE STANDARD LIBERTY AND THE WRIGHT MODEL T-2 ENGINES

of a modified design installed. No other parts were repaired, replaced or refitted. This same engine was then submitted to a second continuous run of 125 hr. at wide-open throttle as shown in the graph numbered 4. At the end of this run the modified pistons were in excellent condition. The valve-seats were again found to be badly eroded, but the valves were still in excellent condition. A careful inspection disclosed no evidence of deterioration or serious wear in other parts. Further testing of this engine was discontinued and it was laid aside until means could be found to overcome the valve-seat difficulties. An entirely new design of cylinder-block was laid out and one block built for test. At the same time changes were made in the cam contour to better the volumetric efficiency and increase the output. A single block of this new design has recently been subjected to five consecutive 50-hr. non-stop runs at full throttle. The graphs numbered from 5 to 9 inclusive indicate the results of these runs. In preparing these latter graphs the output of the single block has been doubled to represent the output that is to be expected from the complete engine. During this 250 hr. of wide-open running, there has been no evidence of any valve trouble, the valves have not been ground nor any adjustment made and both the valves and the seats appear to be in practically as good condition as when originally installed. Two of these new cylinder-blocks with the modified cams have been substituted for the old-style blocks on the same engine that completed the previous 250-hr. test and this engine is now being set-up for further endurance running at wide-open throttle. Aside from the new cylinder-blocks and the cams, this engine is in exactly the same condition as at the end of the previous 250-hr. test; no adjustments, repairs or replacements in other parts have been made. All of the changes mentioned above are being incorporated in new engines under construction, which are known as Model E-4. In Fig. 3 is shown a power curve of the original E-2 and of the modified engine as determined by actual test of assembled engines. While a full 300-hr. test at continuous wide-open throttle has not yet been completed with this engine, the running that *has* been done justifies the prediction that this engine as modified is easily capable of withstanding such a test.

Work of a similar nature to that outlined above has been in progress in all classes of engine for all types of service with very similar results. Invariably, the efforts that have been made have resulted in a marked increase in the durability, and practically without exception changes in the design have at the same time resulted either in a decrease in the weight, an increase in the output, or both. Much remains to be done, of course, but the lessons learned from the development work in one type are usually more or less applicable to all types, and from the tests that have been completed thus far and from those that are now in course of completion, we have become fully convinced that it is a question of only a short time until we shall have a complete line of engines for all types of service operations ranging from 60 to 700 hp., some air-cooled, others water-cooled, which will be capable of withstanding at least 300 hr. of continuous full-throttle running without failure in any part.

The costs involved in overhauling aircraft engines are not generally appreciated. The records of our service show that the standard Liberty engine, a 50-hr. test product, requires a complete overhaul after every 72 hr. of flying operation. Averages show that it requires approximately 300 man-hr. of direct labor at each overhaul to remove a Liberty engine from an airplane, disassemble, clean, repair and refit, reassemble, test and reinstall it in the airplane. This does not include supervision or transportation to and from the shop. In other words, for every hour that the engine flies, 4.2 man-hr. of direct labor must be paid for within the walls of the overhaul shop. Skilled labor is required for this work. I believe that $1.50 per man-hr. is a very conservative figure for the cost of such labor plus overhead, which gives a cost in overhaul labor alone of $6.30 per flying-hr. of the engine. At a cruising speed of 75 m.p.h., this represents an overhaul labor cost of 8.4 cents per mile for a single-Liberty-engine airplane. It does not include the cost of any replacement parts required in connection with the overhaul. These oftentimes reach a value up to 25 per cent of the total cost of a new engine. It does not include the cost of the operating and the field maintenance crews and equipment. The overhaul cost of operating an engine is inversely proportional to

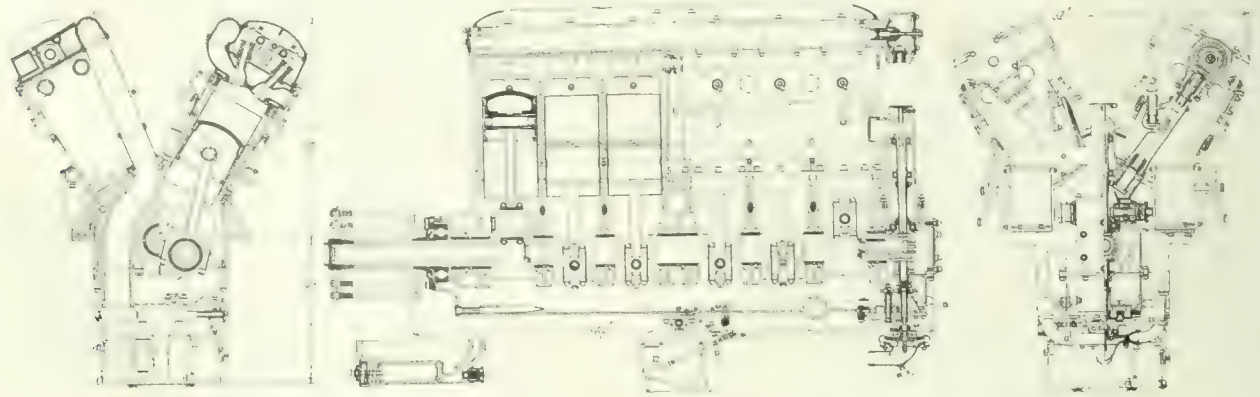

FIG. 5—TRANSVERSE AND LATERAL SECTIONS OF THE WRIGHT T-2 AIRCRAFT ENGINE

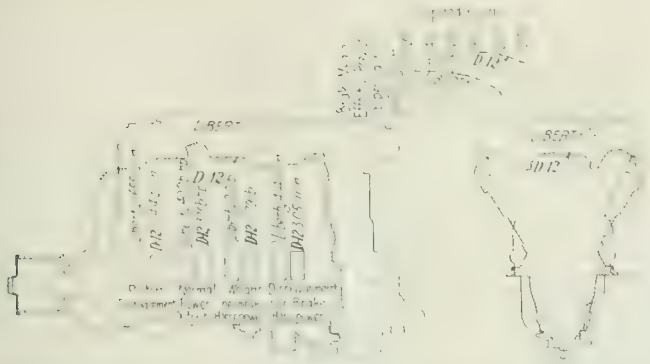

FIG. 6 COMPARISON OF THE STANDARD LIBERTY AND THE CURTISS D-12 ENGINES

the durability of the engine. As I have previously indicated, the 300-hr. wide-open throttle test that we are now coming to adopt as standard is probably the equivalent of not less than 600 hr. of normal flying operation. It requires only a little elementary arithmetic for one to appreciate the importance of this work.

The work that has been done has most forcibly demonstrated two extremely important things, (*a*) that we may confidently predict for the immediate future a degree of dependability and durability in aircraft engines that will at least equal that of the aircraft structure itself, which means that the frequent removal of engines from aircraft for overhaul is not necessary and that the quantity of spare engines and replacement parts can be enormously reduced, and (*b*) that to realize this degree of dependability it is not necessary that the weight per horsepower developed be at all increased over the weights that are present in the ordinary engines of today.

REDUCTION IN WEIGHT

Contrary to a rather widely accepted belief, the features that result in the greater decreases in the weight are at the same time features that inherently tend to increase rather than decrease the factors of safety in vital engine parts. To use a familiar example, a 12-cylinder V-type engine can inherently be made more durable than a 12-cylinder in-line engine of the same weight and power for the reason that the backbone of the engine, the crankcase and the crankshaft, are, due to their shorter lengths, enormously stiffer. Long crankshafts and crankcases are inherently heavy, flexible and weak; short crankshafts and cases are inherently light, stiff and rugged. A multiplicity of parts is, within reasonable limits, an enemy to ruggedness and dependability, and in a large measure at least is incompatible with light weight. Within limits, it requires less weight of metal to enclose a given cylinder volume in a few cylinders of large bore than in a large number of cylinders of small bore, After all, and again within limits, it is the total piston displacement that largely determines the limiting possible output of an engine, not the number of cylinders. The more recent engine designs that have been developed for our service have all been drawn up with these principles in view. Figs. 4 to 9 illustrate the results of this trend in design. Fig. 4 is a comparison of an engine that has been recently developed, the Wright Model T-2 that has 1950-cu. in. piston displacement, a normal output of 550 b. hp. and weighs 1150 lb., with the standard Liberty engine. No weight has been spared in the design of the stressed parts. As a matter of fact, its weight per cubic inch of piston displacement is considerably greater than in the Liberty engine for this reason. But it has on test fully demonstrated its ability to stand up to a 550-hp. output immeasurably better than the standard Liberty stands up to a 400-hp. output, and the weight per effective horsepower output has consequently not been increased. Transverse and lateral sectional views of this engine, which has been completely described in the technical press,[3] are presented in Fig. 5.

Fig. 6 is an outline of a smaller 12-cylinder engine, the Curtiss Model D-12, that is especially adaptable to pursuit work, which has been perfected, during the past year, and which is now being used rather widely in newer types of aircraft. This engine, the propeller end of which is illustrated in Fig. 7, has a total piston displacement of 1145 cu. in., weighs 670 lb., and develops 375 b. hp. at 1800 r.p.m. An engine of this type has recently completed a 100-hr. endurance test without failures or serious deterioration in any parts, and is now being subjected to further testing at full throttle. Previous to the 100-hr. test, this same engine, an illustrated description of which has been published in at least one trade journal,[4] had completed something over 100 hr. of preliminary test running during which certain minor changes in the design were incorporated. So far as the highly stressed parts are concerned, however, no evidence of weaknesses have been uncovered in more than 200 hr. of test running at or above three-quarters power.

Fig. 8 is an outline of another experimental type now under construction. This engine is barely out of the design state at present and for this reason I should hesitate to mention it were it not that it illustrates so well the possibilities in the reduction of weight per unit of power through economy in the crankcase and the crankshaft lengths, rather than by a reduction of the sections in the stressed parts. By an ingenious and somewhat

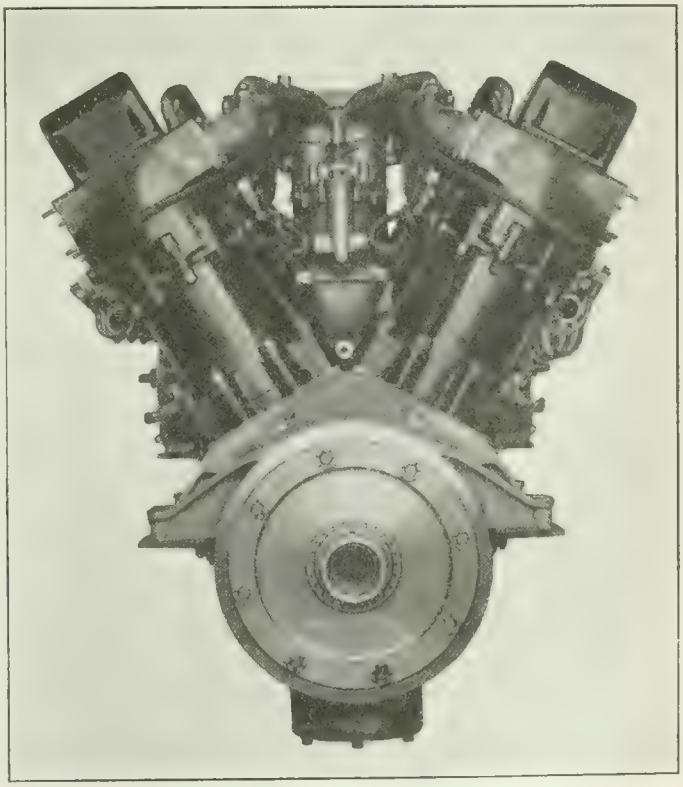

FIG. 7—THE PROPELLER END OF THE CURTISS D-12 ENGINE THAT HAS BEEN DEVELOPED FOR PURSUIT WORK

[3] See *Automotive Industries*, July 13, 1922, p. 57.

[4] See *Aviation*, Oct. 16, 1922, p. 496.

unusual cylinder arrangement and construction, it has been possible to obtain a total piston-displacement of 2450 cu. in. in the extremely small over-all dimensions shown. The weight will be 1150 lb. It has been designed for an assumed output of 775 hp. at 1800 r.p.m. but for purposes of preliminary trials will be rated at 625 hp. at 1650 r.p.m. Its weight per rated horsepower will be 1.80 lb. and on the designed 775-hp. basis its weight will be 1.55 lb. per hp. This engine is not yet completed and hence no test data can be given, but by virtue of the extreme compactness of the design and by a careful study of the stress distribution it has been possible to provide unusually high factors of safety in all the highly stressed parts and still keep the over-all weights extremely low. By virtue of these high factors of safety, the dependability and the durability should be very excellent indeed. Other new experimental models that promise comparable weights per horsepower with excellent durability characteristics are now under construction and are expected to be ready for running tests in the near future.

The practicability of using much larger cylinder-bores than are commonly used in aircraft engines has been under the most careful investigation. A six-cylinder vertical in-line engine that has cylinders of 7-in. bore and 8-in. stroke has been built and recently tested. A complete description of this engine, the Wright Model D-1,

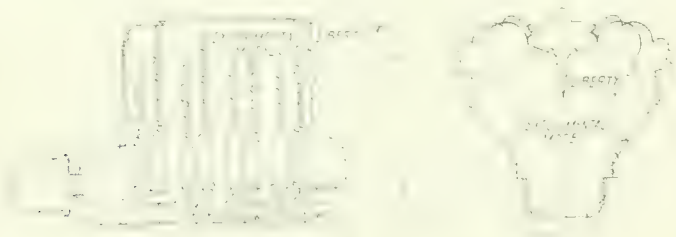

Fig. 8—Comparison of the Standard Liberty Engine and a Recently Constructed Experimental Type

has already been published,[5] and a plan view and sectional elevations of it are reproduced in Figs. 9 and 10. This engine was especially designed for dirigible service which requires certain attributes that are not conducive to extremely light weights, and the weight considerations were subordinated somewhat to these. In the preliminary tests of this engine, much valuable information relative to the performance of the larger-bore cylinders has been gained. Special high-performance runs of a test cylinder have been conducted at a compression-ratio of 6.5 to 1, developing a brake mean effective pressure of well above 140 lb. per sq. in. at 1400 r.p.m. No trouble has been experienced in cooling the pistons or the cylinders either in the test cylinder or in the complete engine. The tests thus far conducted with the complete engine have demonstrated the entire suitability of the design for dirigible service. Further tests are being made and projected to study the possibilities in the use of cylinders of this or even larger sizes in the construction of larger power units for heavier-than-aircraft service.

In this connection, with the use of large-bore cylinders the question of inertia forces is a very serious problem. To offset this difficulty, the use of duralumin connecting-rods and of magnesium pistons has been under serious consideration. Rods and pistons of these materials are being procured for exhaustive block and service tests in Liberty engines with a view to adopting similar practice in all types of engine.

[5] See *Automotive Industries*, April 20, 1922, p. 852.
[6] See The Journal, January, 1923, p. 11.

In all the more recent designs, the possibilities of increasing the rotative speeds and the brake mean effective pressures have been kept constantly in mind and the newer designs have been laid out accordingly. That the factors of safety provided are adequate to withstand overloading has been well demonstrated in special high-power running of the more recent designs. The engine shown in Figs. 4 and 5 has been run for hours continuously at a 20-per cent overload without failure in any part. The engine illustrated in Figs. 6 and 7 has been flown repeatedly in racing service at an output of 450 b.hp. at 2300 r.p.m. without any evidence of failure.

The question of realizing higher specific power and lower specific fuel-consumption through the use of high compression-ratios has been investigated thoroughly. We are indebted to the Bureau of Standards for much valuable research in this line, not the least of which has been a study in collaboration with the Bureau of Mines, of the sources of supply for various anti-knock fuels in the Country. Much of the work that has been done in this connection by the Bureau of Standards has already been presented in a paper[6] read by S. W. Sparrow at the recent Annual Meeting of the Society entitled Testing Fuels for High-Compression Engines. As the result of this work, coupled with a considerable amount of corroborative block and flight testing that we have done with various service types of engine, we have become thoroughly convinced of the entire practicability of using in general service considerably higher compression-ratios than we are now using. The chief problem to be solved is, of course, the procurement of a fuel that will not only eliminate detonation without interfering with proper engine operation in cold weather, and without attacking the materials of the engine, but that will also be readily available for general distribution in large quantities at a reasonable cost. For example, benzol has a tendency to solidify at cold temperatures. Anhydrous alcohol appears to fulfill the requirements very satisfactorily, and we are now after an extensive preliminary investigation, proceeding with final-service tests by conducting all flight operations at three of our air stations, with a blend containing 30 parts of alcohol and 70 parts of gasoline.

The use of higher engine speeds for increasing the output without any increase in the weight is very attractive but is only of real advantage if light weight and thoroughly dependable reduction gears are available. This is one of the most difficult problems that we have had to face. It is a relatively simple matter to make durable gears, but far from simple to make *light* durable gears that will stand up as long as the rest of the powerplant. This problem appears now, after more than 4 years of continuous study and experiment, to have been solved pretty well. One very important development has been the interposing between the crankshaft and the gears of spring couplings that iron out the torsional vibrations and relieve the gear teeth of the immense fatigue stresses imposed with the ordinary rigid connections. We are now proceeding, with confidence, to the construction of dependable and durable gears that have an over-all weight of 0.25 lb. per hp. absorbed, or less.

The Liberty engine, owing to the fact that so many engines of this type are already on hand, deserves more than passing attention. It has been apparent for some time past that the standard Liberty engine has rapidly been falling behind the procession. It has neither the durability, the dependability nor the weight factor to compete successfully with the more modern types. Its life in normal service, as I have mentioned before, is but 72 hr. between overhauls and it requires constant and

FIG. 9—PLAN AND TRANSVERSE SECTIONS OF THE 400-HP. DIRIGIBLE ENGINE DEVELOPED BY THE WRIGHT AERONAUTICAL CORPORATION FOR THE NAVY DEPARTMENT

most meticulous attention at all times. Forced landings due to all manner of minor failures, and occasionally due to major failures, are relatively frequent and not infrequently result in the complete loss of aircraft. We can ill afford to predicate our National defense upon aircraft equipped with this engine, when such aircraft must be called upon to meet on equal terms aircraft equipped with more modern types. Yet we can ill afford to discard the large supply of these engines that still remains in store, bought and paid for, and purchase from present appropriations new engines to replace them.

A careful study of the failures that occur in Liberty engines in service indicates that the weakness of the engine lies primarily in its lack of rigidity, in the manifolding and in the valve-actuating mechanism. Probably the most annoying source of trouble lies in the frequent occurrences of water-jacket leakages in flight. This trouble cannot, apparently, be corrected short of a complete redesign of the cylinders. This is at present being done, experimentally. To kill three birds with one stone, the redesign of the cylinders has taken the form of a six-cylinder aluminum cylinder-block, with a complete new cam-actuating mechanism and an intake-manifolding that follow very closely the cylinder, valve and manifolding design of the more modern types. The use of the block construction enormously stiffens the engine and should, in a large measure at least, eliminate the troubles that have resulted from this lack of rigidity. At the same time the jacket failures are eliminated, while the new valve-mechanism and the manifolds result in a materially improved volumetric efficiency. Other minor modifications have already been made, or are being made, in standard engines in service to correct timing-gear breakages, generator failures, connecting-rod bearing difficulties, piston burning and the like.

The first experimentally modified engine is practically

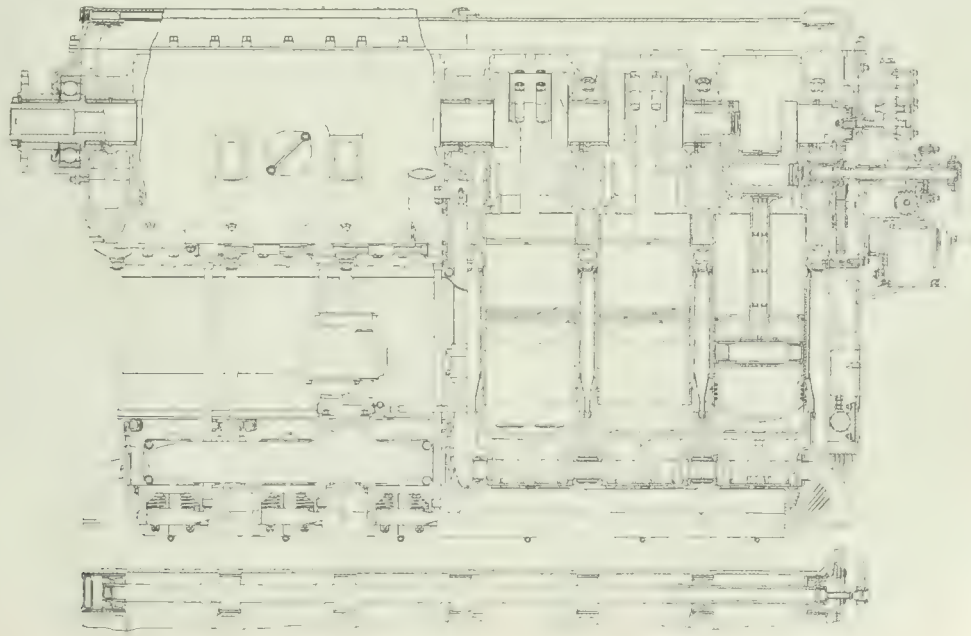

FIG. 10—LONGITUDINAL SECTION OF THE WRIGHT DIRIGIBLE ENGINE

completed and trials of it will be begun in the near future. It is too early as yet to predict with assurance its entire suitability for service use, but the fact that the new parts installed incorporate practically identical features to those now in common use with superior results in the more recent models, should assure a very marked improvement indeed.

In Fig. 11 are given two graphs showing first the present power output of the standard Liberty engine and second the predicted performance of the modified engine, based upon the actual test results obtained with a similar cylinder, valve and manifold construction in other types of engine. Particular attention is drawn to the relatively low brake mean-effective pressure values realized in the standard Liberty engine and especially to the sharp break in the brake mean-effective pressure curve at about 1650 r.p.m. It is this characteristic as much as the frequent cylinder-jacket failures that has led us to a complete redesign of the upper works of the engine.

In this modification we have cut deep, it must be admitted, but after a most careful study and the continuous testing of a number of alternative courses that suggested themselves, we have become convinced that there is no other way. We have been greatly restricted in this work by the fact that modified parts must always be applicable to the standard Liberty crankcase, crankshaft, connecting-rods, pistons and accessories. There is no doubt that the power output shown in Fig. 11 will be realized, nor is there any doubt that the engine as modified will be measurably more durable and dependable than the standard Liberty. The only question is, how *much* more dependable and durable it will be. This is a question that can be answered only by the actual running tests that are about to be begun.

The Air-Cooled versus the Water-Cooled Engine.

I have been rather hesitant about entering such controversial ground as a discussion of the relative merits of the air-cooled and the water-cooled engine, but the work

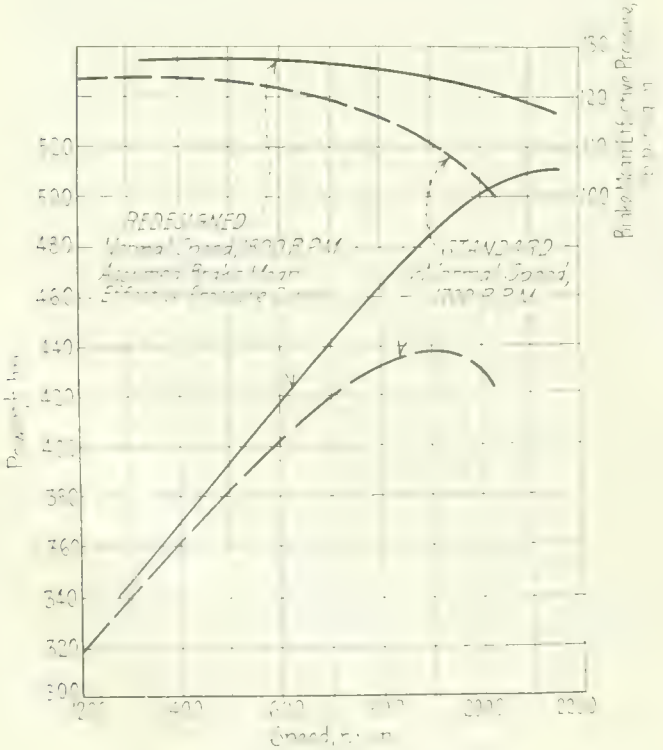

Fig. 11—Comparison of the Power Developed by the Standard and the Redesigned Liberty Engine

that we have been doing during the past 2 years has brought so much definite information to light that the subject cannot well be passed over. If we assume equal durability, flexibility and fuel economy, I believe that every one must agree that the air-cooled engine must have a distinct advantage over the water-cooled engine for aircraft service, owing to the elimination of the weight and the complications imposed by radiators, water and piping. The chief contention between the air-cooled and the water-cooled proponents appears to be one of whether the air-cooled engine can be made to equal the water-cooled engine in these three characteristics. It has also been contended by the water-cooled proponents that the air-cooled engine must, due to its relatively large frontal area, have a much higher head-resistance factor than has the water-cooled engine. These questions have been largely based on surmise. Little really definite comparative information has been at hand, for the simple reason that until very recently there have been no air-cooled engines of any considerable output available in this Country for actual comparative flight tests.

Something over 2 years ago, we began in real earnest an intensive development and testing program to determine definite answers to these questions. The first requirement was of course to get, for flight service, an air-cooled engine that would have an output comparable to more commonly used water-cooled engines. Five engines of an experimental type, the Lawrance Model J, a conventional nine-cylinder radial, having a rated output of 200 hp. at 1800 r.p.m., were contracted for, for development purposes.

The first of these engines was completed about 18 months ago, was placed on a test-stand and test running begun mostly at wide-open throttle. The thermal characteristics of the engines as originally designed proved to be entirely sound and to require no modification. A number of mechanical troubles developed, however, as the tests continued, involving changes in the crankcase design, the crankshaft and main-bearing design, the cylinder securing, the valve-springs, the cams, the accessory drives, the propeller-hub and all manner of minor details. Parallel with these block tests, sample engines have been in actual flight service for a period of nearly a year. The same engine has been flown in weather ranging from the hottest days of summer to the lowest temperature yet encountered this winter, 16 deg. fahr., from sea level to 20,000 ft., in dry weather and rain, in parallel service with the best water-cooled engines of comparable power that we know of today. Troubles have been encountered to be sure, *many* troubles, but they have almost invariably been troubles of a mechanical nature, and without exception means have been found for overcoming them. Not one instance of trouble of any nature has been found that has been at all inherent in the fact that the engine was air-cooled rather than water-cooled. We have found no indication in any of our tests during more than 2 years of constant running of engines of this type that the air-cooled engine as such is less efficient, less flexible, less powerful, less dependable, less durable or more sensitive to changes in the altitude or in the temperature than is the water-cooled engine. It is certainly lighter than the water-cooled engine with its radiator, it requires less preliminary running to warm up in cold weather and less attention on the part of the pilot in flight and its installation is distinctly simpler and cheaper.

To obtain an indication of the relative aerodynamic features of the air-cooled and water-cooled types, we have built for comparative flight tests three types of airplane

that are exactly alike in all respects except for the power-plant installations. One of these types has the air-cooled engine installed, the other two types have two different models of water-cooled engines. Two of these airplanes, one equipped with the Wright Model E-2 water-cooled engine and the other with the Lawrance Model J-1 air-cooled engine, were entered in the Detroit races this year. Unfortunately, the water-cooled type did not finish due to a broken propeller-tip that forced her out of the race. But from comparative flight trials prior to the race and from recorded times for the early laps of the race, it is pretty conclusively established that the two machines, using identical propellers turning at the same number of revolutions per minute, were exactly equal in speed. The power output of the E-2 engine was brought up to that of the J-1 engine by installing in the E-2 special high-lift cams and special pistons to give a compression-ratio of 6.5 to 1. The J-1 engine was in all respects standard.

I regret that our testing program in this regard is not yet completed, and that complete quantitative data are not, therefore, yet available. All information as yet available, however, appears to confirm the results noted during the Detroit races.

The wide investigation that we have pursued during these past 2 years appears to have established beyond the range of surmise the following characteristics for the air-cooled engine of smaller powers up to, say, 300 hp., as compared with the best existing types of water-cooled engines of comparable power.

(1) There is nothing inherent in the air-cooled engine that renders it less durable or dependable as a mechanism than is the water-cooled engine

(2) As regards thermal characteristics, the air-cooled engine is at least the equal of the water-cooled engine. Block and flight tests over a period of many months have demonstrated a specific power and specific fuel-consumption that is the equal of the best water-cooled engines of comparable power that we know of

(3) The air-cooled engine is not unduly sensitive to wide changes in the atmospheric temperatures in flight service

(4) The head-resistance of the radial air-cooled engine of the largest size that we have had in flight, 43-in. diameter overall, is not greater than that of the water-cooled engine of the same power plus the necessary radiator

(5) The air-cooled engine is much more quickly warmed up and made ready for flight in cold weather than is the water-cooled engine and will withstand long glides and dives at a high altitude without interfering with its operation

(6) The air-cooled engine requires less attention on the part of the pilot than does the water-cooled engine

(7) The weight of the air-cooled engine is unquestionably inherently less than that of the best water-cooled engine with its radiator and water. In this connection, I have prepared Fig. 12 to show at a glance a comparison between the dimensions and general characteristics of two actual types now in general use in our service, the Lawrance Model J-1, air-cooled, and the Wright Model E-4, water-cooled. The data shown in this figure represent actual test data for the most recent models of each type. The weight data for each type are based upon the *dry* engine; the water and the radiator of the water-cooled engine are not included. This represents an additional handicap in favor of the air-cooled type of approximately 0.6 lb. per hp.

The conclusions to be drawn from these facts, and they

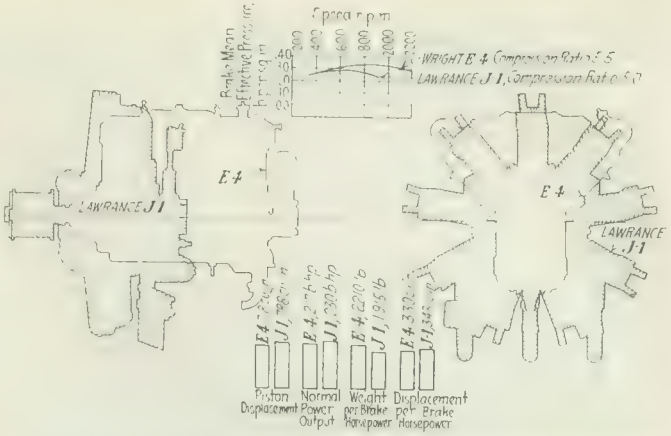

FIG. 12.—COMPARISON OF THE WRIGHT E-4 AND THE LAWRANCE J-1 ENGINES

now are fully demonstrated facts, not surmise, are perfectly obvious.

What are the possibilities in air-cooled engines of larger powers remains to be determined. The engineering division of the Army Air Service has in its excellent research at McCook Field demonstrated the entire practicability of constructing air-cooled cylinders of large displacement that have thermodynamic characteristics equal to the best water-cooled construction. It remains only to solve the relatively simple mechanical details of combining such cylinders into a larger-power engine without exceeding reasonable frontal dimensions. How large diameters are practicable before the head-resistance factor of the conventional radial engine becomes an offset to the other inherent advantages of the air-cooled type is a question that can be decided only by actual flight trials which must naturally wait upon the development of larger air-cooled engines that are now being projected. The question of frontal dimensions is largely a question of mechanical arrangement. We are now investigating valve arrangements that will permit a very material reduction in radial-engine diameters through the elimination of the top hamper now used in the conventional overhead poppet-valve cylinder designs. A highly experimental engine is under construction that entirely eliminates the overhead valve-gear, there being nothing at all above the cooling fins of the cylinder-head proper. It is too early to predict the outcome of this project, but the advantages to be gained not only in the way of head-resistance, but in over-all weight as well, are self-evident.

The air-cooled engine, at any rate in the smaller sizes, has definitely arrived, and is in our service definitely displacing the water-cooled engine in all sizes up to 300 hp. No new types of water-cooled engine in these powers are contemplated. What the future is for air-cooled engines of larger powers we are not yet prepared to say definitely, but the prediction is ventured that just as the air-cooled engine is now displacing the water-cooled types in the smaller powers, so will it extend its field progressively to the larger powers and displace the water-cooled engines in this field.

I have outlined only the more important work that we have been doing along more or less conventional lines, namely in the four-stroke Otto cycle reciprocating engine. These are the things of the present and the immediate future. That we have not confined ourselves to convention alone, you may be sure. Many other lines have been or are being investigated. I have refrained from mentioning investigations that we have been making along other lines, for example, in high-speed solid-injection

auto-ignition engines, in two-stroke cycle engines and others, because all of this work is still in its preliminary stages and is still too full of conjecture to warrant any definite predictions for results as applied to actual aircraft use. It is not to be doubted that radical departures from present conventional practices will, soon or late, gradually or suddenly, find their way into the aviation field, but as yet no new departure has presented itself that appears to give any promise in the immediate future of displacing the present more conventional practices in common use. Our chief hope for betterment, so far as the present is concerned at least, lies in perfecting the kind of apparatus that we have been accustomed to using. And in looking back over the results of the recent development work that has been done with the funds that have been made available to us, we feel that the funds have on the whole been spent to good advantage, that the safety, the dependability and the operating cost of aircraft have been very materially improved, and that the strong commercial aircraft industry that the National defense so sorely needs is thereby much closer to realization than it has ever been before.

APPENDIX

Influence of Powerplant Weight on Transportation Costs

One often hears the statement that the requirements for commercial aviation are very different from those for military aviation, that for commercial aviation one can afford to use considerably heavier engine types than are at present in common use for military aircraft. A rather careful study of the influence of powerplant weight on the amount of pay-load that can be carried throws some interesting light on this subject. I have taken as the basis for comparison the performance of a type of aircraft that has recently been developed, and that has an unusually high carrying load per horsepower by comparison with existing types of aircraft.

The total gross weight of the machine as built is 7175 lb. The engine used is a standard Liberty developing 400 b. hp., which gives a power loading of 17.9 lb. per b. hp., a very satisfactory figure. With a cruising radius of 500 miles this plane as built can carry a pay-load of 1010 lb.

The powerplant weights, exclusive of fuel, are as follows:

	Lb.
Dry Weight of Liberty Engine	872
Engine Accessories	58
Hand Starting System	17
Propeller	58
Dry Weight of Cooling System	132
Cooling Water	113
Dry Weight of Oil System	33
Dry Weight of Fuel System	184
Engine Controls	15
Total Powerplant Weight	1,462

As a basis of comparison, I have taken a purely hypothetical assumption that an air-cooled engine that will deliver 400 hp. and that will weigh 600 lb. dry is available to replace the standard Liberty engine. I believe that such an engine is capable of being built. With such an engine it is reasonable to assume a powerplant weight, exclusive of the fuel which is considered to be the same as in the previous case, of

	Lb.
Engine	600
Engine Accessories	33
Starting System	17
Cooling System	0
Water	0
Dry Weight of Oil System	33
Propeller	58
Dry Weight of Fuel System	184
Engine Controls	15
Total Powerplant Weight	940

Owing to the simpler engine mounting required for the air-cooled engine, there will be an additional saving in the weight that is conservatively estimated at approximately 50 lb. The total saving in the powerplant weight in the case of the latter installation is, therefore

$$1462 - 940 + 50 = 572 \text{ lb.}$$

This saving in the deadweight of the powerplant permits an increase of 572 lb. in the pay-load, without in any way affecting the performance characteristics of the airplane.

Assume that a commercial transportation company has a regular contract to carry 3000 lb. of goods per day, a distance of 500 miles. To fulfill this requirement it will be necessary in the first case to keep three airplanes in continuous operation, while with the lighter powerplant the same work can be done with only two machines, and the relative transportation costs per ton-mile will be 50 per cent greater when using the heavier engine than when using the lighter one.

PROGRESS

A MEDIÆVAL mood of stagnation and apparent finish always precedes the discovery of our new worlds. Correct forecast of the future is so rare because it must be founded upon a disbelief in the stability of things as they are. The young and the speculative are always taken by surprise; but the experienced no longer count on continuity. The apparently so enduring structure into which we are born soon tumbles about our ears. And we, who at first seemed to be moving forward through a fixed world, finally come to regard ourselves as the only fixed thing in it. Life overleaps every bound that is set; and we have to keep advancing our landmarks.

We are born for the future and the past concerns us only secondarily.

To create and at the same time supply a new demand is the highest usefulness. The world wants it, yet never knows it.

Always the most precious gift is one of whose value the recipient is still ignorant. Conditions try to hold us in their service.

If we feel the world's needs, we shall be the right man at the right moment. But if we feel only our own, we shall at most be mental valetudinarians. Many look, one sees; many ought, one does. He is the great man.

Heaven still opens when the right voice vibrates; the rock still gushes when the prophet speaks.—S. B. Stanton.

Painting Practice from the Chemist's Viewpoint

By L. Valentine Pulsifer[1]

Detroit Section Paper *Illustrated with* Drawing

THE paper presented at the meeting of the Detroit Section held on March 2 was a resume and combination of the two papers presented by Mr. Pulsifer at the 1922 and 1923 Annual Meetings of the Society, entitled Manufacture and Application of Automobile Varnishes and Paints, and Automobile Finishing-Varnish, respectively. On account of this duplication, the paper actually presented at Detroit is not printed herewith but in lieu thereof abstracts of the two papers are given below with references to the issues of The Journal in which they were printed, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with the minimum amount of effort.

The procedure following the presentation of the paper was based on a new plan. Cards were distributed among those present, it being asked that questions be written thereon by those who did not care to take part in the discussion orally. After the presentation of the paper the cards were collected and the questions were read by the chairman to Mr. Pulsifer who replied. For that reason most of the discussion appears in the form of questions and answers instead of in the customary arrangement with the names of the different speakers.

ABSTRACTS

DIVIDING the ability of an automobile finish to remain new into the elements of proper quality of the materials, engineering of application systems, methods of application and care of the finish, the author states that the responsibility for them rests jointly upon the manufacturer of the varnishes and paints, the builder of the automobile and the owner of the finished product. Five basic materials that are necessary in automobile painting are specified and discussed.

Engineering systems of application and the actual methods of application are treated in some detail, inclusive of drying, and of surfacing or rubbing. The care of the finish is important and the precautions necessary in this regard are outlined. The paper deals with the application and not the manufacture of the different varnishes and paints that are mentioned. —[Printed in the January, 1922, issue of The Journal.]

AS the success or failure of the finish of an automobile depends largely on the finishing-varnish, a plea is made for more scientific analyses of the problems of automobile finishing and more care in selecting and applying a suitable varnish. The qualities to be desired in a finishing-varnish are divided into two classes: the shop qualities and the service qualities. The shop qualities include color, body or viscosity, working, flowing, setting, hardening, fulness and the safety of working. The service qualities, or those that enable the varnish to withstand the various conditions of use, include resistance to break-down under the chemical action of the actinic rays of sunlight, to the destructive action of moisture and the alkalis in mud and soap, to expansion and contraction, to vibration and to abrasion. The three most important factors in estimating the service-giving qualities of varnish are said to be elasticity, moisture-resistance and the film factor. Each of the various terms mentioned is carefully defined, analyzed and explained. Among the constants that must be determined, either for checking uniformity or for use as bases of tests, are the non-volatile content, which is the starting-point in the test for elasticity and in computing the film factor or thickness of the dried film; the ash, the flash-point, and the acid number. An empirical formula is derived by which the thickness of the dried film can be estimated with accuracy; and in a series of appendixes the details are given concerning tests for the drying, the safety of working, non-volatile content, ash, flash-point and acid number; the Kauri reduction test; and tests for moisture and alkali resistance.—[Printed in the January, 1923, issue of The Journal.]

THE DISCUSSION

Question:—What causes plain finishing to crack or craze on natural wood-wheels?

Answer:—The question, I presume, relates to premature cracking or crazing. Any plain or fancy finish will crack or craze eventually as a result of the chemical destruction caused by the actinic rays in sunlight. Premature deterioration may be due to a lack of elasticity in the finishing material or the use of a too elastic wood filler, with the subsequent finishing of those wheels before the filler was properly hardened. It may also be due to the building-up of the surface on which to apply the finishing with too much rubbing-varnish, instead of treating the parts the way a boat ought to be treated, that is, putting on none but durable materials. The proper way to finish wood wheels is very similar to the proper way to finish a boat. They should get a coat of suitable silex filler, which, if the job is to be tinted, is tinted to match the kind of wood wanted, and then be finished with three coats of a material that approximates a good spar-varnish in quality; if done in that way, the resultant finish can hardly crack and craze before its time.

Question:—Why does enamel or paint peel on some metal? In other words, is there such a thing as pickled metal on which paint will not stick?

Answer:—Evidently something was wrong with the metal; it was pickled too much or it was not properly pickled. All metal does not take paint in the same way. This is especially true of steel; that is, some steels are much more easy to condition for painting than others. As a rule, steels that are capable of being properly drawn into panels show very much better characteristics for painting than the harder steels.

The only answer to this question is that the trouble might be due to 10 or 12 different things. The metal may have had grease-spots on it before it was finished,

[1] Chief chemist, Valentine & Co., New York City.

or incipient rust after the cleaning operation. Unless all the facts are known in a case like that, beginning with the analysis of the metal right straight through to the finish of the job, a specific answer to such a question can hardly be given.

QUESTION:—Which will give the more durable finish, (*a*) the use of an elastic color-sealer over the rough stuff, or (*b*) the use of a flat ground and the japan color over the rough stuff?

ANSWER:—The use of too elastic a pigment sealer-coat will cause trouble by being more elastic than the subsequent color-coats. My opinion is that a sealer-coat should be extremely thin and not relied upon to form the color ground-work as well as to perform the sealing operation; in other words, a coat that merely goes into the rough stuff or the surfacer and seals the pores, practically becoming a part of the rough stuff or the surfacer itself. With a sealer of this description it is possible to use a rough stuff of less toughness and more porosity and therefore easier surfacing qualities, than it is possible to use with good results if the sealer operation be omitted, because you really put the life into the rough stuff afterwards; after you have reached your surface.

There is no reason why a properly brought-up job in a japan color should not give perfect satisfaction. A job brought-up in a very elastic sealer-coat and then followed by a japan color would be very likely to cause trouble, just as one brought-up by the use of an elastic pigmented sealer followed by a more or less short, brittle color varnish, would be likely to cause trouble.

QUESTION:—Why does brass affect paint? How does enamel adhere to nickel or brass?

ANSWER:—Both copper and zinc, the largest constituent parts of brass, are difficult metals to paint. The combination is sometimes more difficult than either one by itself. Brass presents a more or less greasy surface and requires very careful surfacing and cleaning to get it in the shape to take primers properly.

Primers that are suitable for some other metals are not always suitable for brass or bronze. Sometimes it is quite a trick to get a primer that will give the best results on brass moldings or other brass parts. It is a question again of properly cleaning the material. Usually it is best to do the final cleaning with very fine sandpaper dipped in benzol, which gives a slight "tooth" to the brass part, and also makes it extremely clean; and then prime it before it has a chance to oxidize or tarnish.

QUESTION:—What is your opinion of viscosity measurement taken with the MacMichael instrument?

ANSWER:—The MacMichael instrument is too accurate and far too fussy for varnish work. In other words, it involves an unnecessarily fine operation. The best way of measuring the viscosity of a varnish is with the Gardner-Holdt viscometer.

QUESTION:—What viscosity should a satisfactory varnish have? Can a satisfactory varnish be made from materials containing an appreciable amount of rosin?

ANSWER:—The first question cannot be answered. There is no "best" viscosity for every type of varnish for every type of operation. To get the proper thickness of film on a flow-coated panel, a material of different viscosity from that required for brush work should be used. The same viscosity, as a rule, is not wanted in the undercoats as in the finishing-coat, and about the only thing to say is that the varnish should have the proper viscosity to give the best results under the conditions and methods of application.

In the case of a finishing-varnish the proper viscosity is the greatest viscosity that can be handled properly under the painting operation that is being carried on in a given plant; with the limitation that it must not be so great that the varnish from the top to the bottom of the panels does not harden through properly. In other words, if the varnish is too heavy, "case-hardening," with big alligator-cracks and checks, results long before the material should go to pieces.

Rosin is used in the varnish industry in a number of different ways. One of these is in the manufacture of the so-called resinate driers that are compounds of the rosin acids with various manganese, lead and cobalt salts, an indirect method by which these drier materials are frequently introduced into the varnish. These driers are very soluble and therefore can be introduced into the varnish much more easily than straight metallic driers.

Another use of rosin in varnish is that of the so-called ester gums that have as their basis the common South Carolina rosin treated with glycerine. This treatment produces a very low acid-number, and one that can be controlled. Varnishes of this class are particularly valuable as mixing varnishes for colors. The various natural gums have a wide range of acid number. No two lots will be exactly the same. If the gum, whether it is rosin or some other, is not treated in the same way, varnishes of fluctuating acid-number will be obtained and when they are compounded with various pigments fluctuating results will be secured. For that reason, for many types of mixing varnish, and for some other varnishes, a raw material that can be controlled through a chemical process that takes place in the plant itself can be used to good advantage.

QUESTION:—How does second-run turpentine compare with turpentine?

ANSWER:—The so-called first-run turpentine is better than the other because it is usually paler in color. It should be absolutely water-white. Second-run turpentine is very often somewhat off-color and contains a higher percentage of resinous material than the first-run turpentine. For many purposes turpentine should be just as near water-white as possible. In the case of second-run turpentine, where the resinous material is in excess it can be redistilled, and just as good results can be secured from second-run as from first-run by the introduction of this rectifying process. This is, of course, practical only where large quantities are used.

QUESTION:—Is it necessary to lay-up a winter supply of high-grade rubbing and finishing-varnish?

ANSWER:—Not as necessary as it was 30 or 40 years ago. The separation of the drier compounds of the rosin and the oil acids that formerly took place with alarming regularity when varnish was chilled is no longer anywhere near as likely to occur. This does not mean that it is not advisable to lay-in a stock if proper storage space is available. Under extreme low-temperature conditions the best material will occasionally show trouble from chilling.

QUESTION:—Is it possible to mix paint by the eye as nearly correctly as when using a scale and a measure?

ANSWER:—Yes and no, depending on the eye.

QUESTION:—Where can the bubble viscometer be obtained?

ANSWER:—The Gardner-Holdt bubble viscometer can be obtained directly from the Institute of Industrial Research, or by any varnish manufacturer for his customers. This apparatus was developed at the expense of the National Varnish Manufacturers Association. Only a limited number of the instruments can be produced by reason of the difficulty of getting tubes of standard internal-diameter; but they can be obtained from Dr. Harry

Gardner, of the Institute of Industrial Research, City of Washington.

QUESTION:—Can the Kauri reduction-test be used on any but the finish coat?

ANSWER:—Its principal value is in the estimation of the finish-coat, and of clear rather than pigmented varnishes, although, if it is possible with the color material to separate the pigment successfully, the Kauri reduction-figure can be determined for the remaining clear liquid.

In the case of rubbing-varnishes, the bulk of them crack on the bending-test without any Kauri reduction whatever. Merely the application of the original varnish, plus forced drying and the bending operation, will crack them. A reversal of the Kauri reduction-test on the rubbing-varnish can be made by determining the non-volatile content of the material and adding a mixture of bodied linseed-oil and turpentine to bring the varnish *up* to the breaking-point; by finding out how much of this oil compound it was necessary to add, the original elasticity or lack of it can be determined.

QUESTION:—Has the ultra-violet light been used commercially for drying varnish? Does it offer any possibilities?

ANSWER:—So far as I know the ultra-violet light has never been used for drying varnish. It has been used in an accelerated test for colored pigments, and in some research laboratories an attempt is being made to use it as an accelerated durability-test. It is a very good thing for finding out the fading or darkening quality of pigmented goods. It has possibilities in conjunction with the Kauri reduction-test, or perhaps by itself when used on completed systems, of simulating rapid "weathering" in the laboratory.

QUESTION:—Is there any standard method of testing the hardness of the varnish-film after it is dry?

ANSWER:—There is no standard method. One method has been proposed for use with such varnishes as those used on floors, and I presume it could be used for rubbing-varnishes. That is to buy a set of lead-pencils that run all the way from very soft to very hard; cut them down to a chisel-point; prepare the panel; give it the requisite time to dry; then, starting with the softest pencil, draw each of the series in succession over the panel and find out which one makes the first scratch. That sounds somewhat like a foolish method, but strange to say it works very well. As a rule that is not the kind of hardness that is in the mind of the man who is thinking of the hardness of a finishing-varnish. The only method of finding out whether it is hard enough is trying it in production. If it becomes gummed-up with finger-marks and things stick to it, it is not hard enough; if it goes through the regular schedule and does not have these troubles, it is hard enough.

QUESTION:—Do ovens heated to 110 to 120 deg. fahr. kill a large percentage of the oil in the varnish? If so, where does this oil go?

ANSWER:— It takes more than that to kill the oil of a varnish. The boiling point of the vegetable oils used in making varnish is something over 500 deg. A temperature of from 110 to 120 deg. fahr. merely results in a more rapid absorption of oxygen and a denser coat. In other words, it is wholly advantageous and not at all deleterious. Baking at this temperature, or perhaps a higher one, is deleterious only when a varnish that normally dries rather rapidly on the surface is run right from the finishing-room into a heated oven and is dried on the surface before the entire amount of the volatile material has been driven off. Then case-hardening, which is just the reverse of what is wanted, results. A temperature of from 110 to 120 deg. never hurt the life of any varnish under normal conditions.

QUESTION:—Will rubbing-varnish, when not thoroughly dry, cause the finishing-varnish to lose its luster?

ANSWER:—It certainly will; and the same thing will happen with any of the under-coats. The proper result with any conceivable system is based on the proper hardening of each individual coat, all the way down to the priming-coat.

QUESTION:—Can you approximate the number of coats of finish of an automobile body by visual inspection?

ANSWER:—I wish I could. I have seen some jobs that had 15 or 20 coats that looked very poor, and I have seen other jobs with only a few coats that looked fine. In other words, there is no way of measuring the thickness of a thing that you cannot see through without getting through and measuring it.

QUESTION:—Why does paint perish on aluminum more quickly than on steel?

ANSWER:—A certain paint system might perish more rapidly on aluminum than on steel, due to the different coefficients of expansion of aluminum and steel, but no reason in the world exists why an aluminum body cannot be painted to stand-up just as well as one of steel. The only precaution to be observed is not to permit anything in the nature of white-lead to touch the aluminum body, as, if the moisture gets through to that particular coat, it will cause corrosion, perishing and the disappearance of the entire finish. Aside from that there is no reason why a paint job should not last as well on aluminum if the job is properly balanced in elasticity for that particular metal.

QUESTION:—Why does an automobile body that has received a flow-coat job often check or crack near the bottom after several months' exposure to the weather, while the center and top are unaffected?

ANSWER:—That is due to the fact, especially where the flow-coat is used on the rubbing-coats, that the coats at the bottom of the panel are too thick to harden through properly. Then we have the effect of a hard material on top of a soft material, with the result that we get big alligator cracks, starting at the bottom and gradually working their way up.

That can be demonstrated very easily in the case of some flow-coated color varnishes the day after they are put on, by starting a putty-knife up under the coat. It is possible to go about one-third of the way up a door panel before reaching a point where the varnish is hardened through and cannot be removed. In a flow-coated panel the middle is about the normal thickness of a brush coat, so that the bottom is too thick, the middle is about right and the top is too thin.

QUESTION:—What effect do body polishes or automobile soaps have on the finish of a car?

ANSWER:—These two substances produce two different effects, as a rule. Some body-polishes have no deleterious effect, if they are properly used. The chief difficulty with these materials is due to the fact that there are many on the market that are merely thrown together without any regard to what they are apt to do to the finishing-varnish. They often contain abrasive material. Some are properly made, but if the directions on the can or the bottle are followed the finish will be ruined. They are sold as "dry washes," which are supposed to obviate the use of the hose. We are instructed to take a piece of cheesecloth with some of this substance on it and wipe off the mud. The result is, of course, that the mud gathers on the cloth, abrading and scratching the surface. These scratches and abrasions very soon develop

into checks and cracks and, with the expansion and contraction of the surface, the job is naturally rapidly ruined.

As far as soap is concerned, the same oils that are used in making soaps are used in making varnish. If a soap contains free alkali, and most soaps do, when it comes to cutting the oil and the grease, and they are used on the finish-coat to excess, or improperly, they will naturally tend to destroy the life of the finish by a gradual chemical action of the alkali on the oils in the varnish.

QUESTION:—What is the proper way of preparing a surface for the primer coat?

ANSWER:—I believe that nothing can compete with the properly dried sand-blast. Many shops have not a proper sand-blast, and there some other method is necessary. Some materials, used for removing rust, cut deep into the rust and take it off. If those materials are themselves subsequently removed or washed off with a material like benzol, and the job perhaps sprayed with superheated steam and then coated as soon as it is dry, good results can be secured without the use of a sand-blast.

Other methods that are used lead to trouble. One of these is the use of the so-called gasoline that we get now as a final and complete wash for automobile bodies. The ordinary gasoline of today contains considerable high-boiling material that used to be sold under the names of kerosene, cylinder and fuel oils and road tar, and it is a risky thing to use. A better method, by far, is to use benzol or denatured alcohol, or perhaps give a final wash with these materials after using the gasoline.

QUESTION:—Will an all-metal body ever be finished in color and baked at a high temperature?

ANSWER:—"Ever" is a long word, and if that is the crux of this situation I will say "yes"; but when, I do not know. It is also a question, I think, of whether everybody wants to ride in an all-metal body. The wood frame on which the usual body is built is a wonderful deadener for rattles and other noises. While certain cars will undoubtedly eventually come to an all-metal body and be finished with black material, or possibly some day with a colored material, I think there are features of the all-metal body that will have to be considered in addition to the question of whether color of a suitable kind can be baked on it. For certain production purposes the all-metal body is advisable and the proper way to finish it is with a material that can be baked-on at temperatures which, the body being all metal, we can afford to use.

QUESTION:—To what extent is China wood-oil used in finishing-varnish?

ANSWER:—It is used to a large extent blended with linseed-oil. China wood-oil appeared on the varnish-chemist's horizon about 20 years ago; in many cases it was originally seized on as a material for making cheap varnishes that would dry and harden rapidly. However, it possesses very many valuable features. It has a toughness and resistance to moisture, as well as a resistance to alkali, that linseed-oil does not possess. Most of the good varnishes today are a combination of linseed-oil and wood-oil, the particular combination used in any given varnish varying according to the service to which the varnish is to be put.

QUESTION:—Is varnish affected by atmospheric pollution in districts where there are coke-ovens and coaltar by-product plants?

ANSWER:—I think there is no question that if the atmosphere contains a large amount of elements such as are present in the air around coke-ovens, blast-furnaces, cement plants or chemical works, these materials are carried down with the rain onto the body and very often help to stain, and sometimes to destroy, finishing-varnish.

QUESTION:—Why does not varnish last as long as it used to?

ANSWER:—This has a sort of familiar sound. The answer is that it does and it does not. Today it is possible to obtain varnishes of at least double the durability of the best varnish that existed in the heyday of the old carriage-business. But, who ever saw a Brewster brougham going down a side street at 60 m.p.h.! It would not have lasted as long as the varnish. In addition to the much greater severity of service on the modern automobile in many cases varnish is used on automotive work that the old carriage-builder would hardly have used for quick repair-work. In other words, to get by on somebody's schedule, or somebody's idea of drying time, or somebody's idea of price, varnishes are used today to finish automobiles that are far inferior in elasticity and durability to the best grades of carriage varnish. The automobile is out more of the time; it is driven faster; it is washed more carelessly; it is soaked with the fumes of gasoline and smeared with oil and grease. Thus the varnish does not begin to have the chance it had on the old carriage, which was lovingly cared for by some coachman who had been with the family for many years.

On the other hand, varnishes of at least double the durability that we used to get can be procured, although of course no varnish today, on an average automobile, can outlast the best finishing-varnishes on the carriage of 50 years ago, simply because the use to which the article is put is very much more severe. However, we can double, treble and quadruple the durability of the usual automobile-finish by using the best materials and methods available.

QUESTION:—Should varnish be aged by the motor-car builder? If so, why?

ANSWER:—If he buys "that" kind of varnish he ought to age it, but the proper answer is "no." There is no reason in the world why the automotive manufacturer should buy varnish that he has to age. The material is supposed to be ripened and aged properly before it is sent to him. Ageing in the shop is not very likely to help. The use of an unripened varnish is not advisable from any angle.

QUESTION:—Will varnish age in a can after it is cured, or must a certain percentage of oxygen be allowed to get into the tank to age it?

ANSWER:—It is not necessary to allow a certain amount of oxygen to get into the tank to age the varnish. If the tank is constructed so that a large amount of oxygen can reach it, and the varnish is kept there long enough, it will not only age but get "past the cure"; it will absorb so much oxygen that it will lose a certain amount of its initial life before it ever goes on the job.

The destruction of the varnish is a progressive oxidation. This progressive oxidation on the job is accelerated by the chemical rays in the sunlight and by moisture. If we start this oxidation by admitting too much air to our tank, or, as some do, by using blown oil instead of heat-bodied oil in the varnish originally, we set up a condition that is bad and leads to premature perishing. A perfectly sealed can of varnish that was properly aged when the can was first filled will keep indefinitely if stored under the proper conditions.

We had a case many years ago of a shipment of varnish sent to China. After keeping it out there 30 or 40 years the Chinaman wrote that there did not seem to be a ready sale for this material in China, and he wanted to know whether we would be willing to take the ship-

ment back and exchange it for house paint. So the material was sent back to us and, although it left the plant several years before I was born, I enjoyed testing it when it arrived. Both the body-varnish and the rubbing-varnish were in perfect condition. This old fellow had evidently kept the material in a proper kind of place. It had not chilled. If there had been the slightest oxygen leak, the varnish would have been ruined for use, years previously.

QUESTION:—What effect will a mixture of banana oil and alcohol have when used as a body polish?

ANSWER:—Banana oil is amyl acetate, which is a fine solvent for every kind of gum, oil and everything else that ever went into a varnish. Mixed with alcohol it forms about as destructive a combination as anybody could get, other than putting in a little TNT to go along with it.

QUESTION:—What makes a body change color under rain?

ANSWER:—The bluish appearance that is seen on most automobile bodies if it rains on them long enough is due to the absorption by the finishing-varnish of a small amount of moisture. When this moisture is in the finishing-coat we get a white appearance due to the optical effect of having two things of different refractive value together; particles of water mingled with particles of varnish. In some cases, if the rain lasts long enough, the white appearance becomes permanent; but ordinarily it disappears with the first sunshine. If a bottle half-filled with, say, water and benzol, two perfectly clear liquids, that would correspond to perfectly clear varnish and rain water, is shaken vigorously, while the liquids are mixed they will appear white, whereas neither one of them has changed color in the least. The same effect takes place when the body-varnish absorbs moisture, and it disappears when the moisture disappears, just as the two liquids mentioned will separate and both be as clear as ever.

The permanent whitening that occasionally takes place on automobile varnish is due to a chemical change in the varnish induced by either prolonged or frequent wetting. In that case the drier compounds of the varnish take on a molecule of water and become hydrated. In that hydrated condition they are actually white and opaque.

QUESTION:—What makes the outer coat or finishing-varnish peel off after the first year?

ANSWER:—Many of the varnishes used as a finish-coat are lucky to get by the first half-year, although usually the peeling off of a varnish is a kind of destruction that ought not to take place. If the under-coats are proper and the last rubbing-coat is properly surfaced before the finish is put on, the varnish ought not to peel off. It should perish gradually. The actual peeling is due to some condition under the finish, for which the finish itself is not to blame.

QUESTION:—What effect has salt water on paint?

ANSWER:—That depends on the pigment that is contained in the paint. On the varnish itself salt water has not as great an effect as fresh water, for the reason that salt water, due to the salt-content, does not penetrate the varnish-film as readily as pure distilled water. The allegation that salt water is harder on varnish than fresh water is due to the fact that many of the varnishes used on vessels on the seacoast do not last as well as the same materials used in varnishes for boats on inland waters. This is accounted for by dry salt, which acts as an abrasive, being deposited by the salt water on the deck and the rails, rather than by the action of the salt

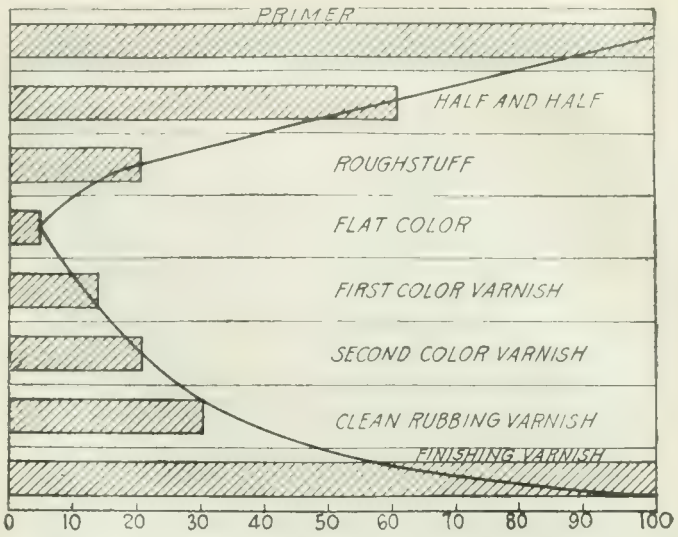

FIG. 1.—CHART SHOWING THE PROPER CORRELATION OF ELASTICITY IN THE VARIOUS COATS

water as such. Fresh water will affect varnish, and usually paint, more rapidly than salt water.

QUESTION:—If the first and last coats give the best results when they are 100 per cent elastic, should not the center coats be more than from 10 to 15-per cent elastic?

ANSWER:—Taking into consideration the number of coats it is necessary to put on an automobile, if an absolute parity of elasticity from the top to the bottom were maintained, the results would not be as good as those given by the curve in Fig. 1. If all these coats had exactly the same elasticity, the result would be as shown. The top coat, of course, gets the bulk of the wear-and-tear, and the bulk of the chemical rays of the sunlight, and the progressive oxidation or rotting goes on more rapidly in the case of the top coat than of those underneath. If all the coats had the same elasticity, the last one would reach a low point of elasticity before the next underneath did, and considerably before the second one underneath, and we would set up in our system the same result that we would get if we upset this elasticity curve to start with. In other words, the finish might, and probably would, go to pieces more quickly if all these coats were of the same elasticity, than they would if we had a proper gradation in elasticity from the primer to the finish.

When it comes to a boat, or a front door, the operation consists of only three or four coats, and it is safe to use these three or four coats of the same elasticity. I believe that is the best practice in such a case. The best way to finish a boat is the best way to finish the wood wheel I spoke of at the beginning of this discussion; that is, put on a proper filler, and then three coats of the same material; that does not apply to a system made up of five different types of material, consisting of from 5 to 10 or 12 coats.

QUESTION:—Should the user inspect his paint and varnish?

ANSWER:—If he is equipped to do so, yes; otherwise he would be wasting his time. I do not know of any industry in which the user of any material ought not to be equipped to test it. I would hate to run a varnish factory if we did not have well equipped laboratories in which to test all the materials we use. The same thing applies to an automobile factory or any other large industrial organization.

QUESTION:—Does the percentage of non-volatile material affect the elasticity factor? Does not the percentage of the thinner change the elasticity factor for the same varnish?

ANSWER:—The percentage of the thinner in itself has no effect on the elasticity of the residual material. On the other hand, the ultimate durability of the finishing-varnish will vary directly with its thickness. Therefore, if we have two varnishes in which the non-volatile content is different but the elasticity the same, the one that will yield the heavier coat will retain its elasticity longer, and consequently wear longer. To a certain extent, the amount of the volatile content of the material has an effect on the ultimate elasticity on the job, although it is an indirect one; it is easier to oxidize completely through a thin coat of material than through a thick one. By "oxidation" in this case I mean the final oxidation that takes place when the varnish rots and perishes.

QUESTION:—Is it good practice to heat metal to reduce the strains due to cold-punching and other mechanical operations, and cool slowly before applying paint coats?

ANSWER:—I doubt it. Unless the metal as designed sets up such strains that it is likely to pull apart itself, the amount of strain that it can induce in the finishing-coats due to its not being properly annealed would be absolutely negligible. The fact that varnish goes to pieces on the cowl of an automobile more readily than on the rest of the car is due entirely to the angle of exposure and not at all to the internal stresses or the actual or imaginary porosity of the material. As a matter of fact, the more porous it was, the better shape it would be in to take the primer. No matter how porous it became, it could hardly become as porous as the wood that formerly was used for the same purpose and gave great satisfaction.

QUESTION:—What is the best method of eliminating mud-spotting on finishing-varnish?

ANSWER:—There are certain exposures to mud that will spot almost any varnish, even the most waterproof material used for a chassis. If mud of a very alkaline nature gets on the varnish when the latter is fresh, and is left on until the mud dries to a thoroughly hard cake, it will leave a spot that will sometimes disappear, and sometimes will not. On the ordinary job, that is anywhere near properly cared for, sunlight as a rule will remove the spots; if not, wiping off with the material that used to be known as lemon oil will usually take out the spots. Sometimes it requires more than one operation to do this. The only way to get rid of those spots is to dry-out the moisture that caused them.

QUESTION:—What is your opinion of the humidity control in the accelerated drying systems?

ANSWER:—The humidity certainly should be controlled in the accelerated drying systems, although, when the materials are dried at low temperatures, which are commonly used, the addition of humidity is not as necessary as is sometimes supposed; but if the higher temperatures are used, it is necessary to have a certain amount of humidity in the air to hold back the evaporation of the volatile material. In other words, if a car were rushed into a very hot oven that was absolutely dry, the solvent would try to "jump out" at once, and the case-hardened effect would naturally follow. The use of humidity is to hold back the evaporation of these solvents; to give the job the proper chance to season through. Of course if humidity is used, it should be under control.

QUESTION:—What causes float in color varnishes?

ANSWER:—To get the desired shade many color-varnishes contain several different pigments. Hardly any two pigments are of the same specific gravity. The light ones tend to come to the top, and the heavy ones to go to the bottom. The result is a float that sometimes causes trouble. The proper balancing of the different pigments, keeping them as close together in specific gravity as possible, their extremely fine grinding and the proper application are the only things that will avoid trouble in a color that is likely to float. The trouble usually appears when one part of a panel is brushed very much longer than the other, and more of the light-weight material is taken off one part of the panel than the other, thereby producing various shades.

QUESTION:—Is varnish a mechanical mixture of the molecules of the gum and the oil? If so, what are the molecules in chemical symbols? If not, what is the symbol of a molecule of varnish? Can you show by chemical symbols the change that takes place in varnish as it is drying, and again its condition when it gets old and is cracking?

ANSWER:—The question of whether varnish is a mechanical mixture or a chemical compound or merely a colloidal suspension is one that is still up for debate. Some parts of the varnish are mechanical mixtures, some are chemical compounds and some are undoubtedly colloids. Exactly which is which is very difficult to say. The combinations of the metallic driers and the oil and the rosin acids are definite chemical compounds. Whether there is a chemical reaction between the gums and the oils is not always apparent. No chemical action takes place between the thinners and the gum-oil base of the varnish. The only way to keep such a collection as that under control is to watch every step in the manufacture with extreme care.

QUESTION:—Why is it necessary to reject varnish after experts have tested and shipped it?

ANSWER:—It is not always rejected by experts. Or the experts who originally passed it may not have been as expert as they were supposed to be. Some varnish is rejected that should be retained and some varnish is retained that should be rejected.

QUESTION:—What is an ideal baking-temperature for black japan or enamel on metal, considering cost, quality and durability?

ANSWER:—I do not feel very well equipped to answer that, as I have had very little experience with materials of that sort.

QUESTION:—What are the characteristics of a good wheel-primer?

ANSWER:—A good wheel-primer is one that sticks to the wheel and allows the subsequent coats to stick to the primer. A good wheel-primer as a rule should be a clear material, to allow inspection of the wheel after it arrives at the automotive plant. It should be a primer that naturally will adhere properly to the wood and have the requisite elasticity and hardness to take the subsequent coats. This refers to wooden wheels. Practically the same answer would hold good for metal wheels, although in that case it does not make any difference whether the primer is clear or pigmented.

A. I. STEVENS:—There seems to be a strong demand from the automobile body-builder to standardize more or less on paint-shop practice and the materials used therein. In view of the variables in the manufacture and testing of varnishes themselves, would it not be difficult to accomplish the standardization for which the body builders are striving?

L. V. PULSIFER:—By that do you mean standard specifications for material or something of that sort?

MR. STEVENS:—Standard specifications with regard to

viscosity and a printed standardization of quality of the varnish itself.

MR. PULSIFER:—I think the whole question of what is the best varnish for any given purpose is still too much involved to talk very strongly about writing automotive-varnish specifications. The United States Government has written very many varnish specifications; some have been good and some have not; but I never have heard that the use of those specifications has been of any great help. An automobile varnish is a complicated thing. When it comes to a product like exterior house-paint, it is usually easier to write specifications that will be of some value, and that can be checked up. When it comes to the specifications written by an automobile builder for a given varnish or a paint material, I think the state of the art in the automotive industry today is at a point where those things are likely to cause more trouble than good. However, the automotive company or the user of any of these materials should most certainly know what the various desirable qualities of varnish are. They should have within their personnel some one who is equipped to make proper estimates; but drawing definite specifications, that the gravity and the viscosity shall be such and such, winding up with material specifications of some sort, as a rule leads to more trouble than value.

The user of the product should cooperate with the people from whom he is trying to buy it, and work out the best material for his particular operation for the particular thing he is trying to arrive at; and then have within his possession the necessary knowledge to check deliveries against the data arrived at under that cooperation.

MR. STEVENS:—I find that I agree with Mr. Pulsifer after all.

E. PLANCHE:—With the instructions that Mr. Pulsifer has given us, together with a good quality of material, under the present use of an automobile in all kinds of weather, how long should the luster on the finish of the body last?

MR. PULSIFER:—An arrangement such as is shown in Fig. 1, with a varnish that showed 100-per cent reduction with the Kauri test, a properly engineered system and anything like decent care, should go safely through at least a year. Most automobiles at the end of a year have been scratched, bumped or dented to such an extent that they require refinishing. A system such as that referred to in which, as I say, the final coat was between 80 and 100 points in elasticity, ought to go through a year to a year and a half in normal use. Of course, under abnormal use or under abuse that time might be reduced to a few months or even a few weeks. It is possible, by beginning to increase the elasticity of the material in the rubbing-coats and reaching an elasticity in the last coat before the finish of say 70 or 80, and then putting on a finishing-varnish of an elasticity that is practically double the normal amount, to run that life up to 2 or 3 years with anything like good service conditions. Of course, many jobs are so engineered and so finished that if they were finished with the *A* varnish in Table 1 that had an elasticity factor of 10, a rather thin film-factor of 35 and a total estimated service figure of 45, the expected life could not exceed from 4 to 6 months at the best, especially on the parts of the job that were exposed flat or up to about 45 deg.

TABLE 1—SERVICE-DURABILITY RATINGS OF FOUR FINISHING-VARNISHES

Finishing-Varnishes	*A*	*B*	*C*	*D*
Elasticity Factor	10	60	90	160
Moisture Resistance	0	10	20	50
Film Factor	35	47	52	36
Service-Durability Rating	45	117	162	246

RESERVE-RATIO OF FEDERAL RESERVE BANKS

THE amount of reserve required for a bank that is a member of the Federal Reserve System depends on the size of the community in which the bank is located and the nature of its deposits. On the average throughout the country the reserve required for a member bank is about 10 per cent of the amount of its deposits payable on demand. In the same way, Reserve Banks must keep in reserve a certain proportion of their funds, and because of the fact that the Reserve Banks carry reserves for other banks, the percentage is much higher, 35 per cent of the amount of their deposits, and 40 per cent of the amount of their notes; but for purposes of convenience and ease of reference the published reserve percentage is a single figure. This figure is the proportion that the total reserves bear to the amount of both deposits and notes. Thus a 75-per cent reserve-ratio or percentage means that the Reserve Banks have reserves in gold or lawful money that amount to three-quarters of the sum of their deposits and notes.

The reserve-ratio of the Reserve Banks may therefore be affected by any one of three factors, a change in the amount of cash reserves, a change in the amount of note issues or a change in the amount of deposits. Changes in the cash reserves, however, affect the ratio more than do changes in either of the other two items.

Present conditions are not such that the gold reserves of the Federal Reserve Banks remains stationary. In the past 2 years it has increased more than $1,000,000,000, practically all of which represents importations of gold. In the early stages of the gold movement, when the gold found its way into the Reserve Banks it paid debts owing by the member banks; latterly it has permitted the member banks to increase their deposits to the highest point ever reached and at the same time to maintain the reserves that the law requires with very little borrowing from the Reserve Banks.

The combined effect of these huge gold imports, increasing the reserves, and of simultaneous heavy redemptions of Federal Reserve notes, decreasing the liabilities, has been to bring about the present reserve-ratio of approximately 77.0 per cent, which compares with the ratio of 85.0 per cent when America entered the war and the ratio of 42.5 per cent in the autumn of 1920 when the credit strain was at its peak.

The present high reserve-ratio, then, is in large part due to the recent flow of gold to the United States from countries that for the time being are not on the free gold basis that obtained before the war. A return to such a basis, under which gold would flow back freely into or out of such countries in settlement of international balances, would, if our balances were adverse, cause a corresponding outflow of our gold. This would decrease our reserve-ratio, exactly as recent imports have increased it.—*Monthly Review.*

Safety and Comfort as Inducements to Air Travel

By R. R. Blythe[1] Annual Meeting Paper

ASSUMING that flying-boat service is safe, the author enumerates some of the reasons people hesitate to fly, inclusive of the difficulty of reaching an airport and the inconveniences of embarking. He states that when the danger to which the passenger believes he is exposed is added, the total deterrents constitute a considerable preventative of the adoption of aviation by the public.

He adds that the recent issuance by the insurance companies of what might be termed a bet of $25,000 with any adult who will fly, at odds of 1000 to 1, that he will arrive safely at the destination, is proof that flying in a sound commercial seaplane is safe at present, and he believes the same guarantee could be secured from insurance companies for airplane passengers flying along properly organized routes over land.

THE average person believes that aviation is a hazardous occupation to be connected with. When he is invited to fly, his usual first impression is that he is going in for an experience that he probably will not have again. He takes the opportunity of going through what he considers a thrilling experience so that he will be able to tell his acquaintances that he has flown in the air. It is conceded by everyone in aviation that thousands of people have flown, and this is a simple concession when one stops to consider that there are at least 100,000,000 people in the United States who could fly as passengers. But, out of that number, the few thousands who have flown do not make up a very remarkable percentage.

How much serious thought has ever been given to what are known as the "repeats"? By repeats I mean persons who having flown once, let us say for business reasons, find this mode of travel economical, fast and comfortable and are willing to undertake other flights for the reason that such flights are beneficial to their business. I think that it will be found that the majority, if not all, of the people who have flown once to get this experience have not undertaken a second flight. There must be a reason for this. We all know that aviation is comparatively safe; so, for the sake of argument, let us forget the question of safety in aviation and confront ourselves with the problems that are likely to affect the mind of the average person.

First, there is the difficulty that prospective passengers have in reaching the flying-fields or airports. Perhaps this is the most vital of all the business-getting problems. Few members of the traveling public are willing to sacrifice themselves in any way in traveling by an interurban trolley-car or an automobile to some landing-field that is on the edge of the suburbs of a city. If the day is cloudy, cold or rainy, there are even greater difficulties such as muddy grounds, the possibility of not being able to fly and the discomforts that accompany bad weather. Thousands of people have not flown and have not even seriously considered flying on account of this alone. A taxicab will call at their door and deposit them inside a warm, well ventilated and well lighted railroad station where their train waits with all the modern comforts. Consider the modern railroad station for a moment and compare it with the modern airport. Is there any inducement to fly?

Second, the passenger arrives at an airport fully prepared to fly, and pays the rather excessive rates that are charged for air travel. In the case of seaplanes, he has to climb aboard a small open boat and, after much shouting and hauling around the bay, the boat finally draws up alongside the seaplane from which are issued the admonitions to the boatman: "Be careful. Do not bump the wing. Swing around and try it again. Hold it off the nose," and several other cautionary orders to keep the boat from breaking what the passenger believes to be a sound, stable aircraft. Finally, after swaying and swinging to-and-fro, he performs an acrobatic feat and gets aboard the seaplane. In the case of airplanes that take-off from a landing-field, the passengers, aided by the pilot, climb up a rather rickety ladder from uneven ground into a cabin having exceedingly close quarters for a limited number of passengers. The roar of the engine is to be considered and also the various inconveniences of taking-off; as well as the troublesome form of exit after landing. Adding to these deterrents the danger that the passenger believes he has been undergoing, we have a considerable setback for the adoption of aviation by the public.

Dangers of Flight

How dangerous is it to fly? The insurance companies recently have issued what might be termed a bet of $25,000 to any man or woman who will fly, at odds of 1000 to 1, that he or she will arrive safely at the destination. The effect of such a bet as 1000 to 1 is to prove that flying in a sound commercial-seaplane line is safe at the present stage, and that this rate will be reduced even further after future experience. Properly organized airplane-routes over land, having a sufficient number of intermediate emergency landing-fields, could easily secure this bet of 1000 to 1 on the safety of airplane passengers.

We must "boost" aviation by all means and impress the public with its safety and its speed, but we must find ways and means to overcome such obstacles as we are facing at present that really have nothing to do with the construction of planes themselves. We have sufficient aircraft speed and safety, but we do not have the conveniences. Without the conveniences, the public will not consider flying.

[The discussion of this paper is printed on p. 352.]

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Motor-Transport Performance with Varied Fuel-Volatility

By C. T. Coleman[1]

Semi-Annual Meeting Paper *Illustrated with* Charts

THE paper is a presentation of data obtained regarding the economic operation of motor vehicles with fuels of varied volatility, under service conditions. The entire fleets of motor-transportation units used by the Post Office Department in Philadelphia and in Pittsburgh were made available for these tests, the resulting data being summarized in the tables and charts, and commented upon briefly.

The test procedure is described and the method of examining the used-oil samples for the percentage of dilution, changes in viscosity, flash-point and fire-test, is explained, inclusive of the tabulated results.

While the results may not hold true for cold-weather operation, they show that the number of car-miles per barrel of crude oil increases as the volatility of the fuel decreases, over the range of fuels used. This is true because the percentage of production per barrel of crude oil is increased, while the number of car-miles per gallon of fuel is not affected materially by the variation in the volatility as represented by the four fuels used.

IN order that natural resources might be conserved and the ever-increasing number of motor vehicles supplied with fuel, every effort has been made in the past few years to refine all the gasoline possible from each barrel of crude oil and still furnish a satisfactory fuel. If a fuel of higher end-point, or lower volatility, could be used economically, gasoline production could be increased, thus postponing possible future shortage.

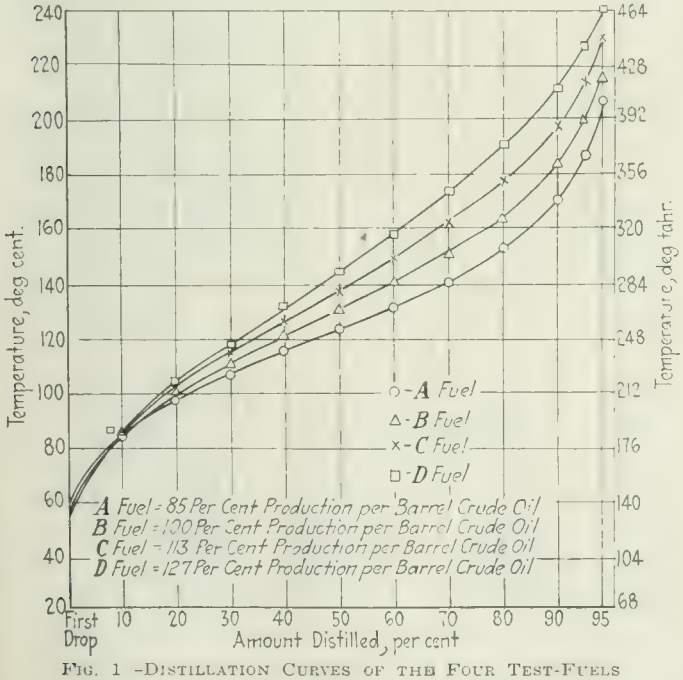

Temperature, deg cent.
Temperature, deg fahr.
Amount Distilled, per cent
First Drop
○-A Fuel
△-B Fuel
×-C Fuel
□-D Fuel
A Fuel = 85 Per Cent Production per Barrel Crude Oil
B Fuel = 100 Per Cent Production per Barrel Crude Oil
C Fuel = 113 Per Cent Production per Barrel Crude Oil
D Fuel = 127 Per Cent Production per Barrel Crude Oil

Fig. 1 —Distillation Curves of the Four Test-Fuels

[1] M.S.A.E.—Associate mechanical engineer, Bureau of Standards, City of Washington.

TABLE 1—CLASSIFICATION OF THE FLEET UNITS

Philadelphia			Pittsburgh		
Number of Vehicles	Size, Tons	Make	Number of Vehicles	Size, Tons	Make
37	$\frac{3}{4}$	Ford	42	$\frac{3}{4}$	White
82	$\frac{3}{4}$	G.M.C.	16	2	White
31	$1\frac{1}{2}$	G.M.C.	16	3	Riker
13	3	Packard	....	....	.....

To the end that some information might be available regarding the economic operation of motor vehicles with fuels of various volatilities, it was believed that a series of tests made under service conditions would furnish valuable data.

A request was therefore made to the Post Office Department for cooperation in a test of this kind. That Department readily agreed and placed at the disposal of the Bureau of Standards, for the purpose of test, its entire fleets of motor-transportation units in Pittsburgh and in Philadelphia. Much credit is due the Post Office Department and the personnel at Pittsburgh and at Philadelphia for the manner in which these tests were conducted. The personnel of the fleets in both these cities made every effort to cooperate with the Bureau of Standards' representative, and the results obtained are a tribute to the efficiency of the personnel conducting it. The combined fleets represented some 237 units of transportation, classified as shown in Table 1. The Philadelphia fleet consumes approximately 1000 gal. of fuel per day, while the fleet in Pittsburgh requires approximately 700 gal. of fuel per day. This combination presented two excellent features; first, a rather large number of trucks well divided in respect to tonnage and make; second, two distinct types of operating conditions, inasmuch as Philadelphia has comparatively smooth streets with few hills, while in Pittsburgh the majority of the streets have a very rough surface and there are many hills.

After a conference with representatives of the American Petroleum Institute, the Society of Automotive Engineers, the Bureau of Mines and the refiners, it was

TABLE 2—ESTIMATED PRODUCTION OF THE FOUR TEST-FUELS

Refiners	Grade *A*, Per Cent	Grade *B*, Per Cent	Grade *C*, Per Cent	Grade *D*, Per Cent
1	81	100	114	128
2	91	100	111	124
3	83	100	113	122
4	84	100	115	133
Average.....	85	100	113	127

TABLE 3—TEST RUNS IN PHILADELPHIA FOR 4 WEEKS ON THE ECONOMIC VOLATILITY OF FUELS

Section No. 1

Car No.	Service Rendered?	Fuel Consumption, Miles per Gal. First Week Grade B	Second Week Grade B	Third Week Grade B	Fourth Week Grade B
Ford Cars					
500	(1)	N.S.	10.19	11.13	13.35
501	(2)	9.73	14.95	7.42	7.12
502	(3)	7.16	9.38	7.20	N.S.
503	(1)	N.S.	12.38	11.43	11.23
504	(1)	8.43	8.73	7.62	7.66
505	(2)	9.58	8.44	8.70	7.22
506	(3)	8.88	12.37	9.88	4.60
509	(1)	7.83	8.26	9.02	8.47
510	(3)	11.36	9.76	8.37	8.32
511	(3)	7.30	6.14	8.00	11.69
512	(2)	8.71	7.42	9.61	8.93
513	(1)	14.54	11.27	11.30	11.09
514	(3)	8.84	8.00	N.S.	6.59
515	(3)	9.82	N.S.	N.S.	N.S.
846	(2)	7.25	6.71	6.48	6.74
847	(3)	8.31	8.62	8.23	9.16
850	(2)	6.22	4.83	6.10	9.03
1,729	(3)	12.48	11.42	11.93	10.51
1,730	(1)	11.83	6.25	10.29	8.67
¼-Ton G. M. C. Trucks					
2,663	(6)	7.82	10.41	7.92	7.00
2,664	(7)	7.62	8.54	9.43	9.17
2,665	(7)	9.20	8.97	8.06	11.60
2,666	(6)	8.99	9.72	9.80	5.44
2,667	(6)	11.10	8.99	8.77	8.68
2,668	(6)	9.98	11.79	12.53	13.59
2,669	(6) and (8)	8.07	8.29	8.44	9.63
2,670	(8)	5.74	5.81	6.89	6.50
2,671	(8)	8.76	5.50	6.40	5.33
2,672	(6)	7.10	6.35	6.06	6.00
2,673	(8)	11.44	5.42	6.02	5.73
2,674	(6)	9.91	7.30	6.65	7.06
2,675	(6)	9.75	6.94	7.93	9.19
2,676	(1)	5.80	4.28	5.64	4.96
2,677	(2)	8.10	9.27	8.91	8.14
2,678	(8)	3.08	8.51	7.95	5.70
2,679	(2)	5.48	7.74	7.72	8.31
2,680	(7)	8.50	8.61	10.23	8.68
2,681	(7)	5.73	5.19	5.02	6.05
2,682	(7)	5.99	5.92	5.73	5.40
2,683	(6)	6.72	6.69	6.98	6.64
2,684	(7)	5.67	5.00	4.84	5.12
2,685	(7)	4.42	5.73	6.34	5.97
2,686	(7)	6.76	5.21	6.01	6.31
2,687	(6)	7.87	7.07	7.22	7.13
2,688	(6)	7.84	9.01	4.87	6.55
2,689	(6)	7.64	5.55	4.67	6.46
2,690	(7)	6.47	4.89	5.67	7.39
2,691	(1)	4.10	6.62	6.23	7.41
2,692	(6)	8.48	7.50	5.46	8.28
2,693	(7)	6.20	6.11	6.02	6.06
2,694	(7)	8.04	6.55	6.35	5.43
2,696	(7)	9.59	8.06	8.83	8.00
2,697	(7)	10.51	7.48	9.84	8.77
2,698	(7)	8.42	7.48	7.19	7.40
2,699	(7)	9.42	10.17	9.00	8.59
2,700	(7)	6.95	6.52	6.12	5.65
2,717	(7)	8.37	6.83	9.00	7.32
2,718	(7)	7.56	5.28	5.63	6.96
2,719	(3)	8.18	7.40	7.97	8.03
2,720	(3)	9.17	7.02	8.94	9.66
1½-Ton G. M. C. Trucks					
3,033	(7)	8.55	5.81	5.97	6.13
4,306	(8)	9.04	5.71	5.29	8.70
4,311	(3)	6.73	7.30	5.84	5.38
4,317	(8)	6.21	4.11	8.11	6.09
4,318	(8)	3.41	3.14	3.12	3.16
4,321	(8)	3.62	4.12	3.60	4.53
4,347	(3)	6.33	N.S.	N.S.	N.S.
4,440	(3)	6.00	4.00	N.S.	N.S.
4,442	(8)	6.03	4.03	4.46	4.57
4,852	(8)	4.00	3.92	4.84	4.67
4,854	(8)	4.88	5.29	5.46	5.25
4,856	(8)	7.15	6.32	6.16	6.93
4,858	(8)	2.66	4.33	4.32	3.55
5,012	(10)	3.05	3.11	4.00	4.68
5,014	(8)	6.60	4.80	4.19	4.63
5,016	(3)	6.10	5.57	9.67	4.29
3-Ton Packard Trucks					
6,168	(8)	2.34	2.53	4.83	2.67
6,301	(8)	2.77	4.75	2.90	3.59
6,303	(8)	3.77	3.97	3.32	3.11
6,421	(8)	3.13	3.06	3.88	3.80
6,423	(8)	2.86	2.86	2.60	2.70
6,425	(8)	2.61	2.64	2.61	2.31
6,495	(8)	3.03	3.54	2.52	3.03

Section No. 2

Car No.	Service Rendered	Fuel Consumption, Miles per Gal. First Week Grade B	Second Week Grade A	Third Week Grade C	Fourth Week Grade D
Ford Cars					
1,708	(5)	13.84	13.54	13.31	7.50
1,710	(5)	9.06	7.51	7.80	9.49
1,711	(5)	12.31	12.04	11.26	10.83
1,712	(5)	11.97	17.24	17.18	14.18
1,714	(5)	13.80	12.14	13.40	14.44
1,715	(5)	8.00	8.20	10.34	10.37
1,716	(5)	7.71	7.89	N.S.	N.S.
1,717	(5)	10.56	11.90	11.84	12.54
1,718	(5)	8.41	9.08	9.67	9.90
1,719	(5)	9.96	9.72	10.15	9.26
1,720	(5)	5.40	11.58	14.08	12.84
1,721	(5)	8.95	9.31	8.72	8.96
1,722	(5)	10.87	12.81	9.88	11.58
1,723	(5)	8.53	7.44	8.77	9.40
1,724	(5)	12.32	12.91	9.06	10.79
1,725	(5)	7.74	9.76	11.26	11.30
1,726	(5)	11.77	13.16	11.63	11.11
1,727	(5)	9.98	9.52	8.37	9.46
1,728	(12)	8.32	9.11	7.09	10.62
¼-Ton G. M. C. Trucks					
2,332	(7)	10.69	10.82	13.51	10.94
2,333	(7)	8.91	10.34	10.51	10.00
2,334	(7)	5.77	6.98	8.22	11.11
2,335	(7)	10.86	8.08	7.45	6.58
2,336	(3)	9.92	6.97	6.14	5.45
2,419	(7)	6.29	6.36	9.54	7.50
2,422	(7)	5.93	5.79	6.18	5.57
2,423	(7)	7.36	6.32	4.40	7.63
2,424	(7)	7.17	7.02	7.39	7.28
2,425	(3)	N.S.	6.70	3.41	8.60
2,426	(3)	7.35	N.S.	6.67	5.85
2,427	(3)	9.46	8.52	8.48	9.00
2,428	(3)	4.67	4.56	10.47	5.63
2,429	(7)	9.04	8.62	8.94	9.84
2,430	(7)	6.94	6.70	7.50	7.46
2,431	(7)	7.02	8.82	6.94	9.02
2,432	(7)	4.71	4.15	5.41	5.14
2,433	(3)	8.99	8.09	2.73	5.50
2,434	(7)	N.S.	11.09	10.85	12.83
2,435	(7)	7.71	5.19	5.60	4.51
2,436	(7)	5.79	6.54	7.27	8.80
2,446	(8)	7.11	9.72	9.46	8.41
2,450	(8)	10.29	10.27	10.71	12.29
2,451	(8)	10.17	10.90	11.21	10.91
2,452	(8)	4.07	4.79	5.22	3.69
2,453	(8)	5.59	5.22	5.66	5.07
2,454	(10)	10.89	8.68	9.75	8.91
2,455	(8)	9.95	8.20	9.32	11.00
2,456	(8)	5.88	6.00	6.48	6.61
2,457	(8)	7.17	7.36	6.80	6.52
2,458	(8)	11.56	12.32	10.27	9.26
2,459	(3)	5.19	5.60	5.88	6.76
2,460	(7)	6.48	6.32	9.12	8.93
2,461	(1)	5.48	5.90	5.14	4.04
2,462	(1)	7.69	8.56	9.17	9.86
2,463	(2)	8.85	9.48	7.18	6.94
2,464	(2)	6.21	6.78	10.13	8.11
2,465	(6)	10.93	14.33	10.74	10.51
2,466	(7)	7.96	11.42	9.51	10.71
2,660	(7)	9.21	7.88	8.15	7.83
2,661	(3)	8.02	6.00	7.26	7.47
2,662	(6) and (8)	6.42	5.66	6.95	9.34
1½-Ton G. M. C. Trucks					
4,304	(8)	6.36	4.22	5.85	7.21
4,309	(8)	5.86	5.44	4.21	4.84
4,314	(8)	7.77	5.31	5.85	8.13
4,317	(3)	4.49	4.77	6.16	5.79
4,319	(6)	6.33	5.74	6.93	8.38
4,330	(8)	4.72	5.40	5.84	6.32
4,851	(8)	5.21	5.53	6.61	4.32
4,853	(8)	3.74	4.01	3.96	4.67
4,855	(8)	5.05	6.55	4.63	5.14
4,857	(8)	5.24	5.04	4.58	4.18
5,011	(8)	4.43	6.26	6.12	4.94
5,013	(8)	4.79	5.22	5.80	5.08
5,015	(8)	4.03	3.62	3.23	3.96
5,017	(8)	6.74	5.27	5.99	8.44
8-402	(4)	3.92	6.99	6.34	8.62
3-Ton Packard Trucks					
6,169	(8)	3.19	2.84	3.16	4.70
6,302	(8)	3.04	5.18	3.39	5.06
6,420	(8)	3.47	3.46	3.09	3.11
6,422	(8)	3.29	3.02	3.16	3.47
6,424	(8)	5.02	3.35	1.94	2.75
6,493	(3)	4.00	N.S.	.....	4.35

See page 345 for explanatory notes.

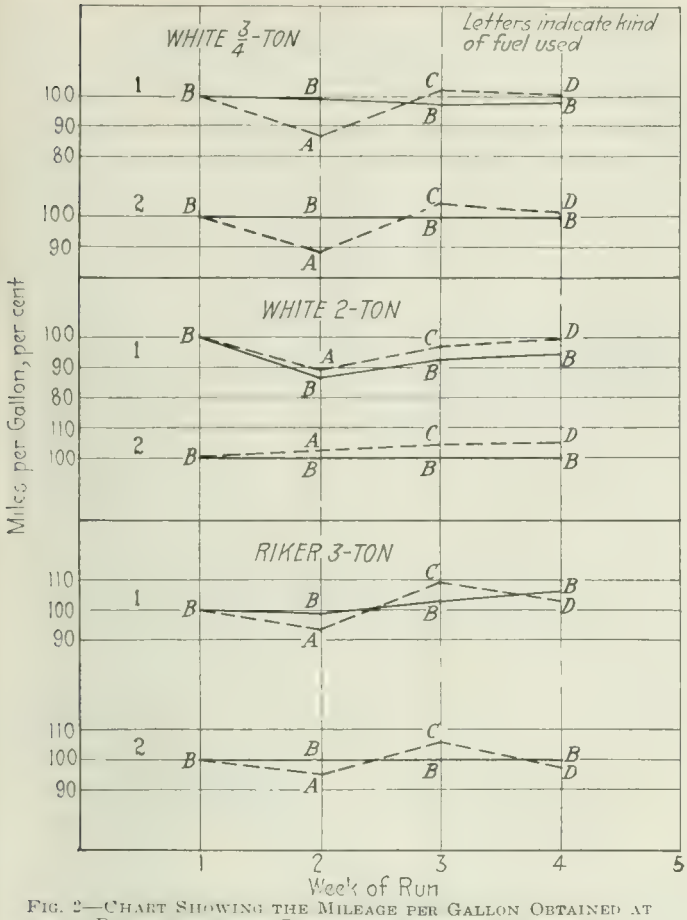


FIG. 2—CHART SHOWING THE MILEAGE PER GALLON OBTAINED AT PITTSBURGH WITH DIFFERENT MAKES OF VEHICLE

decided that, for comparative purposes, the same four fuels should be used in this test as were to be used in the Society of Automotive Engineers' Cooperative Fuel Tests. These fuels are styled Grades *A*, *B*, *C* and *D*. Grade-*B* fuel represents the average commercial gasoline on the market at present, and is used as a comparative or reference fuel. Grade-*A* fuel is of higher volatility, or lower end-point. Grades-*C* and *D* fuels represent lower volatility and higher end-point in the order of their alphabetical designation.

The average distillation-curves for the fuels used are shown in Fig. 1. Compared to Grade-*B* fuel, these fuels represent the average production per barrel of crude oil shown in Table 2.

In testing these fuels the following relative information was sought:

(1) Miles per gallon compared to Grade-*B* fuel
(2) Crankcase dilution in the engines run on these fuels as compared to dilution using Grade-*B* fuel
(3) Performance in service, particularly as to starting of engines, idling and general operation

TEST PROCEDURE

The following methods of test were used: The transportation units in Pittsburgh and in Philadelphia were each divided into two equal parts or sections designated as Section No. 1 and Section No. 2. In dividing the units, one-half of the total number of each make of truck was placed in each section. This method gave two sections equal in respect to the number of vehicles as well as to the capacities and makes.

One section of the fleet was at all times operated on Grade-*B* fuel in order that differences due to changes in weather conditions might be noted and allowed for in the final comparisons. Each truck in Section No. 1 was designated by the numeral 1, placed in some convenient place to be recognized by the truck dispatcher and the men putting fuel into the tanks. The same method was applied to Section No. 2, where the numeral 2 was placed.

From each section, three trucks of each make were

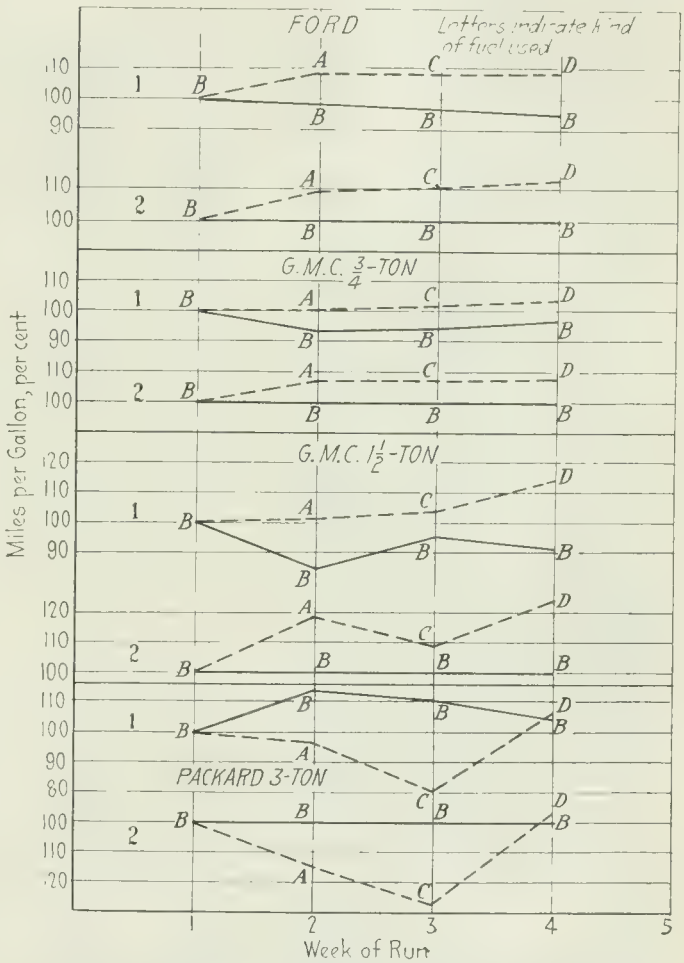
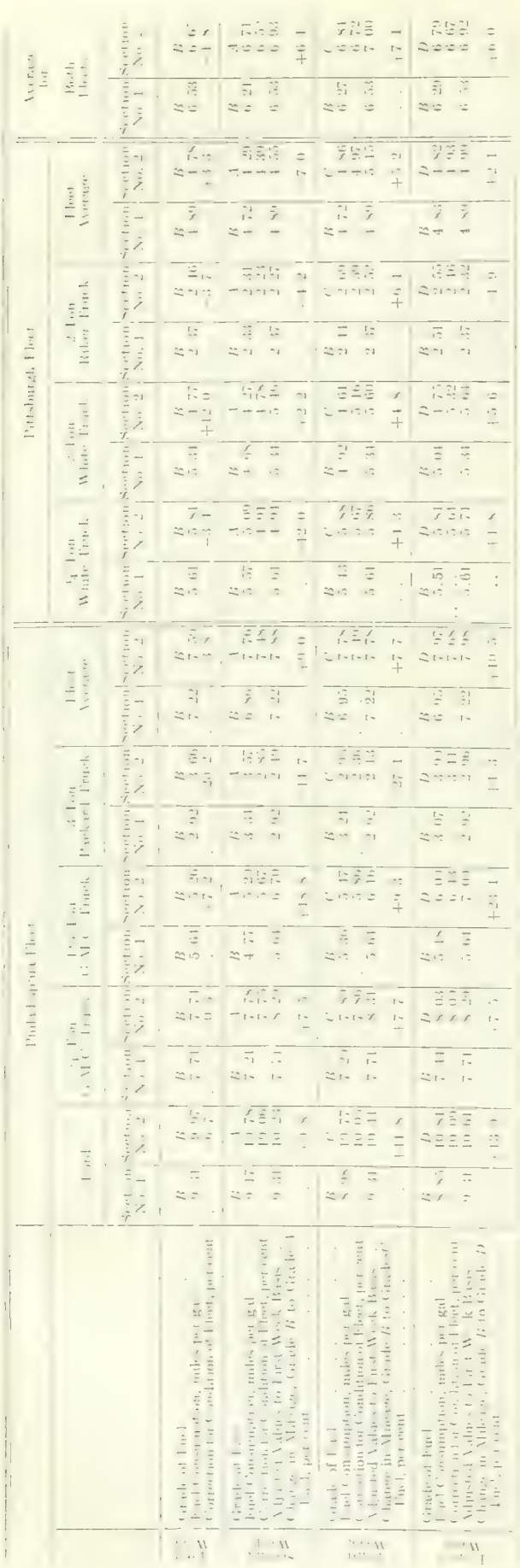


FIG. 3—CHART SHOWING THE MILEAGE PER GALLON OBTAINED AT PHILADELPHIA WITH DIFFERENT MAKES OF VEHICLE

EXPLANATORY NOTES FOR TABLE 3

(1) *Pouch Service*—Carrying pouches of first-class, special and registered mail, from the Central Post Office to and from the various sub-stations. The trucks are handicapped by the congested conditions in the alleyway at the Central Post Office.
(2) *Package-Box Collections*—Collection of mail from package boxes.
(3) *Reserve*—Extra cars placed in service when regular trucks are disabled or when the volume of mail to be transported is excessive.
(4) *Service Car*—Stationed at the Central Post Office for truck repair there; responds to service calls also.
(5) *Letter-Box Collection*—Collecting mail from letter-boxes.
(6) *Interstation*—Carrying mail between the Central Post Office and sub-stations; same handicap as for (1).
(7) *Parcel Post*—Delivery of parcel-post mail.
(8) *Screen-Wagon*—Hauling mail between the Central Post Office and the railroad depot; same handicap as for (1).
(9) *Equipment and Repair Truck*—Used for repairing letter-boxes, box-posts and the like.
(10) *Registry Truck*—Hauls registered mail between the Central Post Office and the Pennsylvania Railroad depot.
(11) *Registry Car*—Hauls registered mail to the banks.
(12) *Truck Supervision*

TABLE 4—INDIVIDUAL-VEHICLE AND FLEET AVERAGES FOR FUEL CONSUMPTION



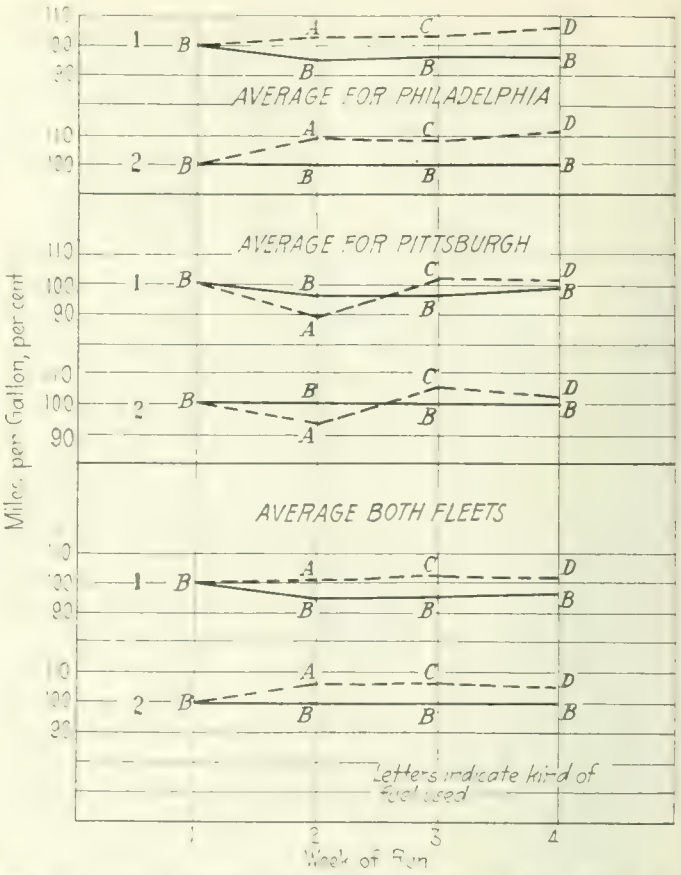


Fig. 3—Average Mileage per Gallon of Fuel for Each Week of the Test at Philadelphia and Pittsburgh and the General Average for Both Fleets

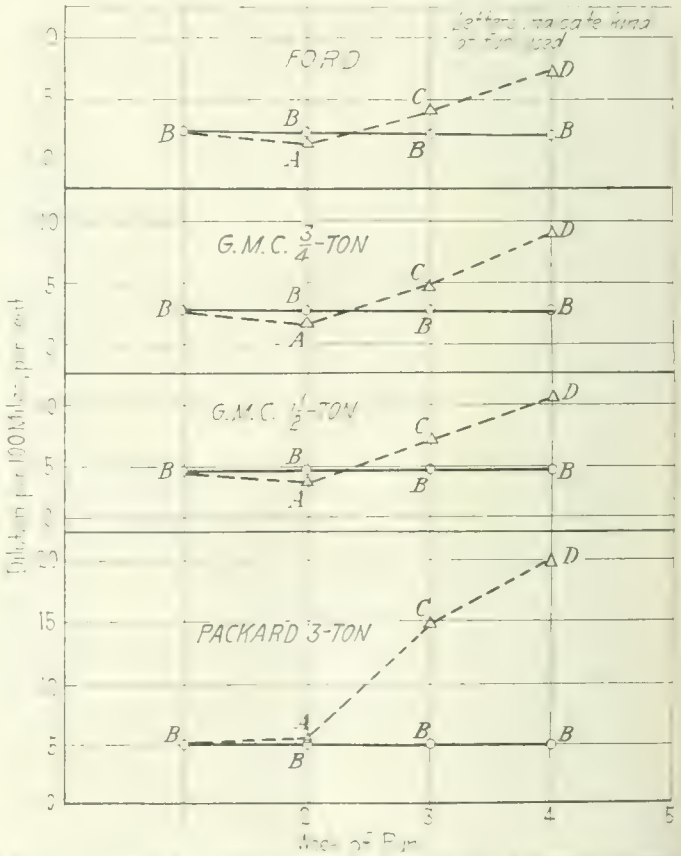


Fig. 4—Chart of the Crankcase Dilution of the Trucks Tested at Philadelphia

selected; the crankcases were drained of used oil and new oil was put in each week or period of the test. At the end of each run or each week a 1-qt. sample was drained from each engine thus selected and labeled as to the truck number, the make, the kind of fuel and the mileage. Each truck was labeled with the letter corresponding to the kind of fuel on which it was operating. This letter was placed in such a manner that mistakes were unlikely in placing the proper fuel in the tank.

The schedule of test was as follows:

First Week—Both sections were run on Grade-*B* fuel. All trucks were drained, the fuel was placed in the tank and the mileage was noted. At the end of the week the fuel remaining in the tanks was drained and measured, and this amount was deducted from the total fuel put into the tanks during the run. The mileage was noted at the end of a run

Second Week—Section No. 1 continued on Grade-*B* fuel and Section No. 2 was run on Grade-*A* fuel; the same procedure was followed as for the first week.

Third Week—Section No. 1 continued on Grade-*B* fuel and Section No. 2 was run on Grade-*C* fuel, following the same procedure as in the two previous runs

Fourth Week—Section No. 1 was again continued on Grade-*B* fuel, and Section No. 2 was run on Grade-*D* fuel, following the same procedure as in the preceding weeks

As each shipment of fuel was placed in the supply tanks, a 1-gal. sample was taken and labeled as to the date and the kind of fuel. Distillations were run on these samples to check the fuel delivered by the refinery. All samples were shipped to the Bureau of Standards at the City of Washington, where the laboratory tests were made

Table 3 gives the individual truck averages for each week of the four-week runs. A wide variation will be noted in miles per gallon for trucks of the same make, which may be explained by differences in the engine condition and adjustment, the type of service and the

TABLE 5—MISCELLANEOUS DATA ON OIL USED

Period	Kind of Oil	Make of Truck	Truck No.	Number of Miles	Grade of Fuel	Section No.	Philadelphia Samples: Initial Point Deg. Cent.	Initial Point Deg. Fahr.	Percentage Distilled at 300 Deg. Cent (572 Deg. Fahr.)	Gravity Specific	Gravity Baume	Viscosity at 100 Deg. Fahr., Saybolt Sec.	Flash-Point, Deg. Fahr.	Fire-Test, Deg. Fahr.
First Week	New Medium						(a)300	(a)572.0		0.906	24.5	316	415	475
	Used Medium	Ford	850	143	B	1	163	325.4	5.0	0.905	24.7	293	285	440
			512	244	B	1	165	329.0	6.0	0.900	25.6	280	240	390
			513	349	B	1	182	359.6	4.0	0.902	25.2	298	315	435
			1,711	308	B	2	185	365.0	3.5	0.904	24.9	320	315	450
			1,708	350	B	2	168	334.4	4.0	0.902	25.2	294	325	440
			1,710	253	B	2	180	356.0	4.5	0.902	25.2	299	305	410
		4-Ton G.M.C.	2,691	127	B	1	171	339.8	6.5	0.900	25.6	242	255	345
			2,679	284	B	1	178	352.4	7.0	0.899	25.7	247	235	345
			2,692	352	B	1	188	370.4	11.0	0.895	26.4	170	(b)	(b)
			2,463	433	B	2	180	356.0	9.5	0.898	25.9	208	215	360
			2,466	225	B	2	179	354.2	7.5	0.902	25.2	258	225	445
			2,458	352	B	2	148	298.4	9.0	0.899	25.7	203	210	415
	New Heavy						300	572.0		0.931	20.4	486	430	500
	Used Heavy	1½-Ton G.M.C.	4,318	109	B	1	165	329.0	8.0	0.898	25.9	249	215	345
			3,033	201	B	1	175	347.0	8.0	0.899	25.7	234	210	320
			4,858	145	B	1	168	334.4	4.0	0.901	25.4	315	275	435
			4,304	240	B	2	148	298.4	11.0	0.893	26.8	167	175	255
			4,851	213	B	2	160	320.0	7.0	0.898	25.9	230	230	370
			4,319	242	B	2	135	275.0	5.5	0.900	25.6	247	210	410
		3-Ton Packard	6,425	141	B	1	170	338.0	6.5	0.898	25.9	200	215	360
			6,303	130	B	1	173	343.4	8.5	0.898	25.9	260	210	320
			6,168	114	B	1	176	348.8	3.5	0.901	25.4	265	235	415
			6,302	129	B	2	155	311.0	3.5	0.902	25.2	326	240	455
			6,169	136	B	2	150	302.0	14.5	0.890	27.3	153	130	185
			6,434	197	B	2	158	316.4	8.0	0.900	25.6	284	195	330
Second Week	New Medium						(a)300	(a)572.0		0.906	24.5	316	415	475
	Used Medium	Ford	513	355	B	1	175	347.0	3.0	0.900	25.5	266	320	455
			512	245	B	1	150	302.0	7.5	0.898	25.9	212	220	375
			850	217	B	1	170	338.0	8.0	0.897	26.0	211	225	405
			1,710	311	A	2	152	305.6	4.5	0.903	25.0	300	270	450
			1,711	287	A	2	156	312.8	3.0	0.903	25.0	303	335	475
			1,708	357	A	2	167	332.6	2.5	0.902	25.2	294	255	450
		4-Ton G.M.C.	2,679	282	B	1	162	323.6	8.5	0.897	26.1	206	205	350
			2,691	139	B	1	175	347.0	5.5	0.900	25.5	240	255	400
			2,692	352	B	1	160	320.0	11.0	0.893	26.7	181	200	285
			2,463	417	A	2	156	312.8	7.5	0.897	26.1	210	205	395
			2,466	191	A	2	130	266.0	6.0	0.899	25.7	238	225	410
			2,458	355	A	2	150	302.0	7.0	0.897	26.1	221	205	430
	New Heavy									0.931	20.4	486	430	500
	Used Heavy	1½-Ton G.M.C.	3,033	186	B	1			8.5	0.897	26.1	231	185	350
			4,858	145	B	1	168	334.4	4.0	0.900	25.6	279	230	450
			4,318	113	B	1	163	325.4	7.0	0.898	25.9	233	210	350
			4,304	227	A	2	155	311.0	8.0	0.898	25.9	194	185	335
			4,851	36	A	2	160	320.0	2.5	0.892	26.9	268	265	460
			4,319	241	A	2	135	275.0	4.5	0.899	25.7	243	210	455
		3-Ton Packard	6,303	119	B	1	157	314.6	4.5	0.901	25.4	253	230	455
			6,425	116	B	1	150	302.0	5.0	0.898	25.9	207	210	415
			6,168	96	B	1	157	314.6	4.0	0.901	25.4	254	240	475
			6,424	137	A	2	148	298.4	5.5	0.898	25.9	225	200	405
			6,169	129	A	2	145	293.0	13.0	0.888	27.7	123	145	190
			6,302	156	A	2	152	305.6	3.0	0.901	25.4	255	230	460

(a) Temperature of 5-per cent distillation. 370 deg. cent (698 deg. fahr.)
(b) Insufficient amount of oil.

operators. Table 3 also gives the duties of the trucks in Philadelphia. The low mileage on some of the trucks used in letter-box collection-service can be understood better when it is realized that these trucks make an average of some 300 stops in the course of an 8-hr. tour of duty. The trucks in Pittsburgh are required to perform service similar to that of those in Philadelphia, except that the ¾-ton White trucks used in Pittsburgh for letter-box collection-service do not make as many stops in a tour of duty as do the Fords in Philadelphia. Table 4 gives the averages of individual trucks in both fleets, compared with Grade-*B* fuel.

It will be noted that a slightly higher mileage was obtained with the less volatile fuels. This can be explained by the fact that, as the volatility is decreased, the viscosity of the fuel increases and therefore, with a fixed carbureter-setting, slightly less fuel will pass through the carbureter jets and a leaner mixture will result. The difference in mileage therefore is due to a change in the mixture-ratio rather than in the fuel volatility.

The curves in Figs. 2, 3 and 4 give the individual averages of trucks in both cities and the average for both fleets. Curve No. 1 for each make of vehicle shows the actual percentage of change before any correction has been made for the change in the operation on Grade-*B* fuel. Curve No. 2 shows the results after correcting.

A study of these results will show that it seems to make very little difference in the miles per gallon when a truck is operating on any one of the four fuels, under the warm-weather conditions that prevailed while this test was run, and within the range of accuracy possible in a test of this kind. Little or no trouble was experienced in operating on the various fuels, except for a slight difficulty in starting on the Grade-*D* fuel and the necessity of more throttle-opening for proper idling.

Method of Examining Oil Samples

The following procedure was followed when testing used-oil samples for the percentage of dilution. The initial-point of the new oil was ascertained at atmospheric

TABLE 5—MISCELLANEOUS DATA ON OIL USED—*Concluded*

Philadelphia Samples

Period	Kind of Oil	Make of Truck	Truck No.	Number of Miles	Grade of Fuel	Section No.	Initial Point		Percentage Distilled at 300 Deg. Cent. (572 Deg. Fahr.)	Gravity		Viscosity at 100 Deg. Fahr., Saybolt Sec.	Flash-Point, Deg. Fahr.	Fire-Test, Deg. Fahr.
							Deg. Cent.	Deg. Fahr.		Specific	Baume			
Third Week	Used Medium	Ford	850	177	*B*	1	(*c*)		4.0	0.903	25.0	337	350	460
			512	245	*B*	1	168	334.4	6.5	0.899	25.7	171	230	400
			513	356	*B*	1	163	325.4	5.0	0.900	25.4	260	285	455
			1,711	287	*C*	2	186	366.8	6.0	0.901	25.3	248	280	410
			1,710	238	*C*	2	175	347.0	6.5	0.901	25.3	267	255	385
			1,708	107	*C*	2	190	374.0	6.0	0.901	25.3	241	270	400
		3-Ton GMC	2,692	362	*B*	1	152	305.6	8.5	0.898	25.9	210	200	300
			2,691	134	*B*	1	176	348.8	5.0	0.899	25.7	241	255	440
			2,679	278	*B*	1	167	332.6	5.0	0.899	25.7	267	255	435
			2,458	368	*C*	2	168	334.4	18.5	0.885	28.2	115	170	225
			2,463	412	*C*	2	170	338.0	17.0	0.890	27.2	134	190	235
			2,466	270	*C*	2	183	361.4	13.0	0.894	26.6	165	210	285
	Used Heavy	1½-Ton GMC	3,033	200	*B*	1			8.0	0.898	25.9	235	205	385
			4,318	103	*B*	1	150	302.0	7.5	0.897	26.0	259	185	300
			4,858	136	*B*	1			3.5	0.901	25.4	293	270	445
			1,304	240	*C*	2	160	320.0	13.5	0.891	27.1	175	180	245
			4,319	245	*C*	2	160	320.0	9.0	0.898	25.9	209	210	340
			4,851	108	*C*	2	173	343.4	6.5	0.898	26.2	230	230	400
		3-Ton Packard	6,303	123	*B*	1	151	303.8	4.0	0.901	25.4	314	230	475
			6,425	115	*B*	1	147	296.6	4.5	0.899	25.7	255	215	235
			6,168	140	*B*	1	164	327.2	4.0	0.901	25.4	315	225	475
			6,424	69	*C*	2	170	338.0	9.0	0.894	26.6	178	195	285
			6,169	143	*C*	2	155	311.0	30.0	0.871	30.7	77	140	175
			6,302	145	*C*	2	172	341.6	6.5	0.899	25.7	248	220	445
Fourth Week	Used Medium	Ford	850	158	*B*	1			3.0	0.907	24.3	339	345	465
			512	259	*B*	1	107	224.6	4.0	0.904	24.9	325	290	445
			513	294	*B*	1	187	368.6	2.5	0.903	25.0	306	375	455
			1,710	309	*D*	2	205	401.0	8.0	0.898	25.9	252	260	400
			1,711	287	*D*	2	205	401.0	6.5	0.900	25.5	261	280	395
			1,708											
		3-Ton GMC	2,679	249	*B*	1	175	347.0	4.0	0.902	25.2	306	260	435
			2,692	298	*B*	1	172	341.6	7.5	0.899	25.7	229	210	375
			2,691	122	*B*	1			5.5	0.899	25.7	267	255	440
			2,463	378	*D*	2	185	365.0	30.5	0.876	29.8	84	180	205
			2,458	287	*D*	2	170	338.0	36.0	0.874	30.2	71	255	440
			2,466	182	*D*	2			19.0	0.891	27.1	149	215	250
	Used Heavy	3-Ton Packard	6,425	83	*B*	1			5.0	0.899	25.7	287	215	445
			6,168	131	*B*	1	174	345.2	4.0	0.901	25.4	333	245	480
			6,303	101	*B*	1	162	323.6	3.5	0.903	25.0	350	255	475
			6,302	119	*D*	2	178	352.4	6.0	0.898	25.9	272	220	385
			6,424	114	*D*	2	175	347.0	18.5	0.886	28.0	138	190	215
			6,169	127	*D*	2	160	320.0	31.0	0.872	30.5	82	145	190
		1½-Ton GMC	4,858	117	*B*	1	174	345.2	3.0	0.902	25.2	330	275	460
			4,318	109	*B*	1			6.5	0.900	25.5	285	220	450
			3,033	38	*B*	1	168	334.4	7.0	0.898	25.9	289	210	390
			4,304	202	*D*	2	180	356.0	18.8	0.896	26.2	143	185	235
			4,851	67	*D*	2	190	374.0	8.0	0.896	26.2	200	230	330
			4,319	201	*D*	2	185	365.0	9.0	0.896	26.2	140	215	335
				2,460		(*d*)	175	347.0	24.0	0.882	28.7	100	185	215

(*c*) Contained water.
(*d*) Four-week run with four fuels.

pressure, using a 100-cc. sample in an Engler flask with a water-cooled condensation apparatus. Employing the same apparatus with the used oil, the percentage distilled over at the initial-point of the new oil was noted. This was termed the percentage of dilution. To check this method, samples of new oil were diluted with known percentages of the distillates from the used oil and distillations run on these samples. The results obtained agreed with the known percentage of dilution.

Following the method outlined, the results obtained for the percentage of dilution from the several trucks operating on the different fuels are shown in Tables 5 and 6. Used-oil samples were also examined for changes in viscosity, specific gravity, flash-point and fire-test; the results are shown in Tables 5 and 6 also. The curves in Figs. 5 and 6 show relative crankcase dilution per 100 miles for the four fuels. The curves in Fig. 7 give the fleet averages for both Philadelphia and Pittsburgh. In considering the average dilution for both fleets, it will be noted that, compared with the trucks run on Grade-*B* fuel, those run on Grade-*A* fuel had less crankcase-oil dilution, and that Grades *C* and *D* gave correspondingly more crankcase-oil dilution. From these values the curves shown in Fig. 8 were plotted for

TABLE 6—MISCELLANEOUS DATA ON OIL USED

Pittsburgh Samples

Kind of Oil	Make of Truck	Truck No.	Number of Miles	Grade of Fuel	Section No.	Initial Point		Percentage Distilled at 300 Deg. Cent. (572 Deg. Fahr.)	Gravity		Viscosity at 100 Deg. Fahr., Saybolt Sec.	Flash-Point, Deg. Fahr.	Fire-Test, Deg. Fahr.
						Deg. Cent.	Deg. Fahr.		Specific	Baume			
New Heavy						300	572.0	.....	0.904	24 9	486	430	500
Used Heavy	¾-Ton White	2,114	360	*A*	2	134	273.2	8.0	0.898	25.9	292	180	350
			360	*B*	2	153	307.4	10.0	0.896	26.2	260	170	295
			360	*C*	2	....	....	10.0	0.897	26.1	200	190	300
			390	*D*	2	165	329.0	4.0	0.902	21.8	333	220	390
		2,106	306	*A*	2	146	294 8	4.5	0.902	25.2	308	205	445
			255	*B*	2	160	320.0	8.0	0 899	25.7	317	190	385
			306	*C*	2	175	347.0	8.0	0.901	25.4	313	210	385
			296	*D*	2	170	338.0	9.5	0.897	26.1	278	115	265
		2,236	210	*A*	2	138	280.4	22.0	0.886	28 0	118	125	160
			180	*B*	2	140	240.0	23.5	0.879	29.3	104	130	185
			190	*C*	2	134	273.2	36.5	0 869	31.1	80	130	165
			170	*D*	2	135	275.0	21.5	0.904	24.9	123	155	200
		2,113	204	*B*	1	144	291.2	9.5	0 897	26.1	256	165	450
			170	*B*	1	130	266.0	9.5	0.896	26.2	261	185	335
			170	*B*	1	140	284.0	7.5	0.898	25.9	284	190	375
			183	*B*	1	132	269.6	10.0	0 895	26.4	246	180	275
		2,105	363	*B*	1	163	325.4	7.0	0.904	24.9	441	255	480
			240	*B*	1	154	309 2	5.0	0 903	25.0	419	250	300
			288	*B*	1	150	302.0	6.5	0.901	25.4	366	230	470
		2,705	240	*B*	1	....	.....	6.0	0.902	25.2	390	250	445
			350	*B*	1	....	.....	12.0	0.891	27.1	214	195	240
			280	*B*	1	....	....	13.0	0 891	27.1	192	160	220
			341	*B*	1	160	320.0	9.0	0 897	26.1	286	185	310
			393	*B*	1	147	296.6	14.5	0.889	27.5	176	160	200
Used Heavy	2-Ton White	4,868	226	*A*	2	143	289 4	7.5	0 899	25.7	280	175	300
			190	*B*	2	152	305.6	8.5	0.899	25.7	289	185	310
			228	*C*	2	160	320.0	11.0	0.895	26.4	234	180	275
			228	*D*	2	.	..	15.0	0 891	27.1	186	170	220
		4,878	90	*A*	2	152	305 6	4.5	0.902	25.2	384	230	505
			90	*B*	2	162	323.6	5.0	0 902	25 2	407	170	360
			90	*C*	2	178	352.4	5.5	0.901	26.9	354	225	410
			94	*D*	2	....	..	6.0	0.899	25.7	338	235	400
		4,876	114	*A*	2	148	298 4	7.0	0.892	26.9	208	180	245
			114	*B*	2	150	302.0	9.0	0 898	25.9	251	190	350
			114	*C*	2	170	338.0	11.5	0 898	25.9	273	170	360
			114	*D*	2	156	312.8	7.0	0.898	25.9	273	220	345
		4,881	246	*B*	1	....	.....	6 5	0.901	26.9	344	220	405
			205	*B*	1	..	....	4.0	0.903	15.0	436	230	465
			246	*B*	1	160	320 0	6.0	0.901	26.9	367	210	420
			246	*B*	1	167	332.6	3.5	0 903	25.0	453	255	440
		4,867	208	*B*	1	165	329.0	8.5	0 898	25.9	275	185	445
			228	*B*	1	162	323 6	8.5	0.897	26.1	257	180	280
			228	*B*	1	..	.	6.0	0 899	25.7	310	200	345
		4,873	226	*B*	1	163	325 4	9.0	0 896	26.2	262	185	340
			451	*B*	1	167	332.6	8.5	0.898	25.9	366	180	315
			468	*B*	1	165	329.0	4.5	0.903	25.0	424	235	415
			451	*B*	1	168	334.4	11.0	0.895	26 4	261	185	275
			407	*B*	1	156	312.8	5.5	0.901	26.9	388	210	460
Used Heavy	3-Ton Riker	6,470	170	*A*	2	138	280.4	9.0	0.894	26.6	247	165	350
			188	*B*	2	....	..	26.0	0.877	29.6	93	180	210
			182	*C*	2	164	327.2	12.0	0 891	27.1	204	170	205
			78	*D*	2	152	305.6	9.5	0 894	26.6	238	175	285
		6,472	108	*A*	2	158	316.4	11.0	0 894	26.6	214	175	245
			81	*B*	2	163	325.4	13.0	0.894	26.6	198	170	215
			97	*C*	2	173	343.4	8.0	0.896	26.2	263	205	400
			114	*D*	2	166	330.8	13.0	0.891	27.1	190	185	225
		6,484	88	*A*	2	145	293.0	10.0	0.893	26.8	209	145	275
			98	*B*	2	.	....	13.0	0.890	27.3	173	170	195
			90	*C*	2	160	320.0	14.0	0.899	25.7	170	150	215
			88	*D*	2	155	311.0	15.5	0.885	28.2	143	155	195
		6,481	117	*B*	1	150	302.0	12.0	0 891	27.1	190	165	220
			112	*B*	1	143	289.4	20.0	0.883	28.5	142	135	185
			100	*B*	1	127	260.6	12.5	0.891	27.1	185	170	195
			114	*B*	1	(e)	.....	18.5	0.882	28.7	128	140	170
		6,485	74	*B*	1	160	320.0	13.0	0.890	27.3	187	190	230
			118	*B*	1	160	320.0	13.5	0 889	27.5	174	160	190
			126	*B*	1	160	320.0	13.0	0.888	27.6	184	170	220
			184	*B*	1	158	316.4	13.5	0.891	27.1	197	120	215
		6,475	212	*B*	1	152	305.6	15.5	0 886	28 0	156	145	195
			199	*B*	1	158	316.4	15.0	0 889	27.5	160	160	185
			202	*B*	1	155	311.0	17.0	0 886	28 0	145	145	170
			169	*B*	1	160	320.0	11.0	0.893	26.8	202	170	250

(e) Considerable water.

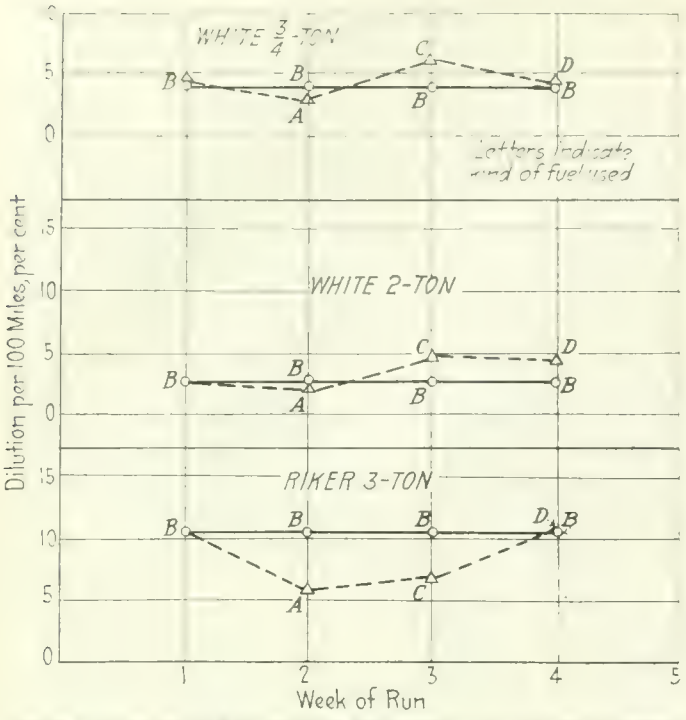


FIG. 6—CHART OF THE CRANKCASE DILUTION OF THE TRUCKS TESTED AT PITTSBURGH

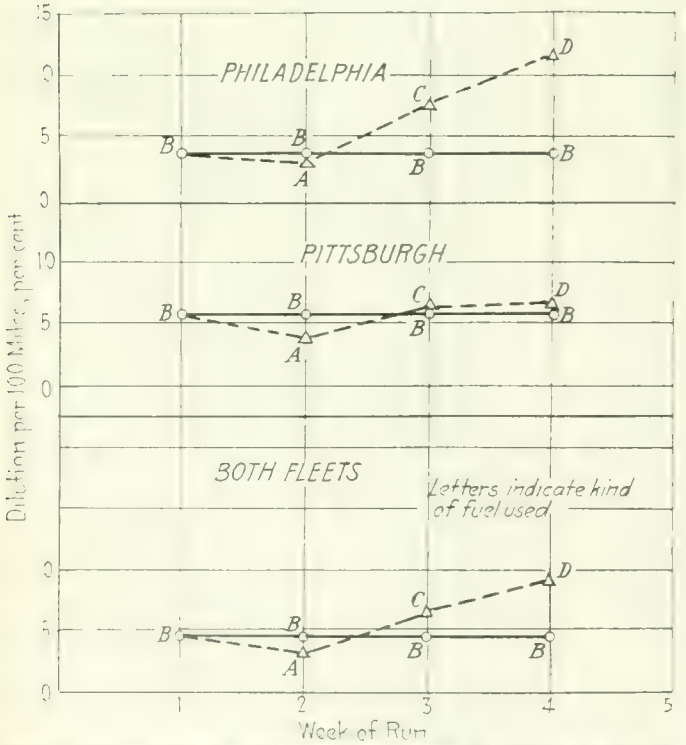


FIG. 7—CHART OF THE AVERAGE CRANKCASE DILUTION AT PHILADELPHIA AND PITTSBURGH AND THE GENERAL AVERAGE FOR BOTH FLEETS

the percentage of dilution against the temperature from the distillation curves of the 85 and 95-per cent points. The curves show that, as the end-point of the fuel is increased, the dilution of the oil is materially increased.

To compare the change in viscosity and specific gravity due to dilution, samples of new oil were diluted with the distillates from used oils to the following percentages: 5, 10, 15, 20, 25, 30, 35 and 40 per cent. These samples were then examined for viscosity and specific gravity. The results are shown in the curves of Fig. 9. The points in the small circles represent the changes noted in the viscosity and the specific gravity of used oils of known percentage of dilution.

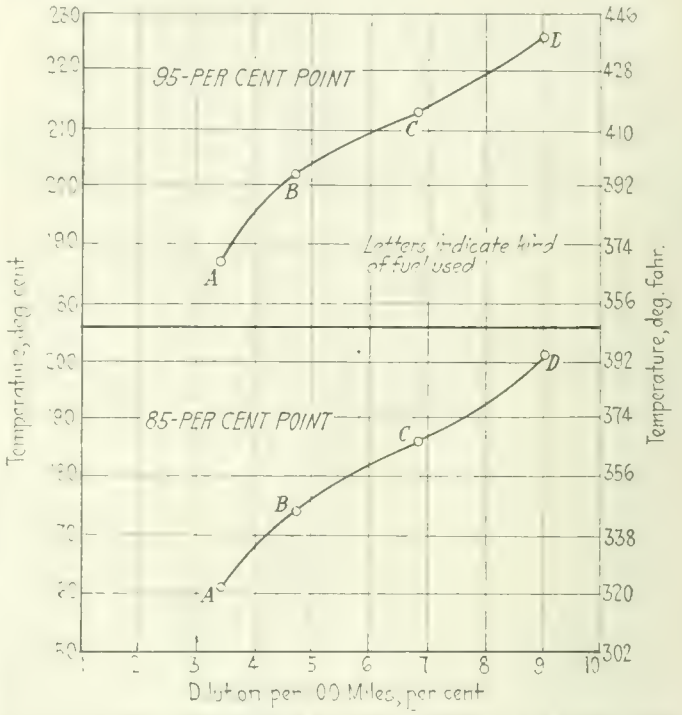

95-PER CENT POINT
85-PER CENT POINT
Letters indicate kind of fuel used
Temperature, deg. cent
Temperature, deg. fahr.
Dilution per 100 Miles, per cent

FIG. 8—CURVES SHOWING THE RELATION BETWEEN THE PERCENTAGE OF DILUTION PER 100 MILES AND THE TEMPERATURES OF THE 85 AND 95-PER CENT DISTILLATION POINTS

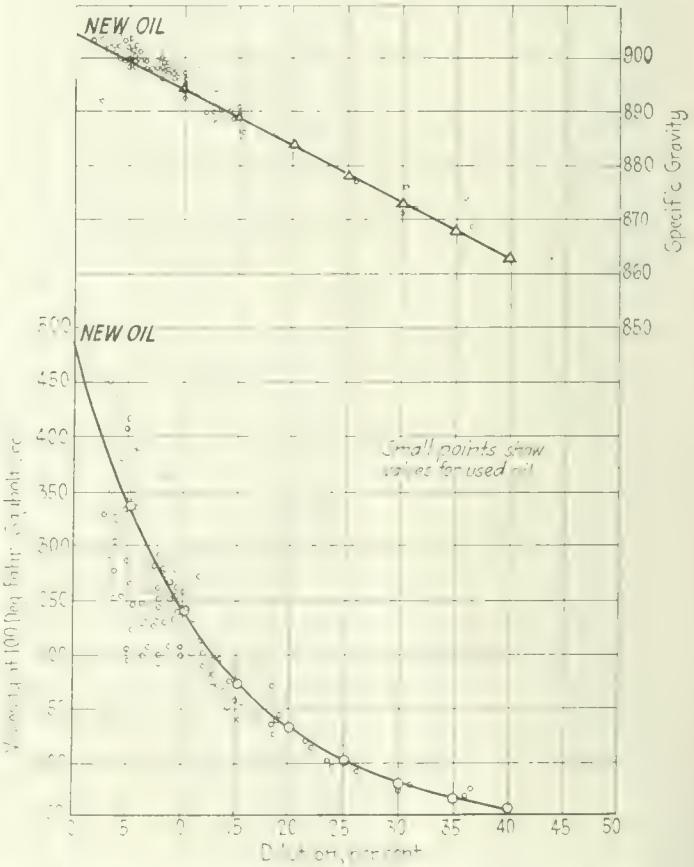


FIG. 9—CURVES SHOWING HOW THE VISCOSITY AND THE SPECIFIC GRAVITY OF THE NEW LUBRICATING OIL CHANGED WHEN DILUTED WITH VARYING PERCENTAGES OF DISTILLATES FROM THE USED OIL

Passenger-Carrying Flying-Boat Operation

By H. A. Bruno[1]

Annual Meeting Paper

THE author states that commercial aviation is an accomplished fact as proved by the successful operation of the flying-boats he represents, and cites performance-records in proof. He finds it most difficult to convince the public that flying is safe.

The different types of flying boat in use are mentioned and the author discourses in regard to influencing the public to fly, citing the successful 90-min. flying-boat service between Cleveland and Detroit, and the other similar successful services, as inducements. He concludes with a plea that all who are interested in the success of commercial aviation support its pioneers.

WE have found that the existing type of flying-boat is capable of taking care of the demand of today. I have often heard engineers say that the moment we design a machine capable of carrying 15 to 20 passengers at reduced rates, we will have commercial aviation in this Country. We have commercial aviation here today. Time and time again we read of what they have done in Europe but, when it comes to over-water air-transportation, we are ahead of Europe. To quote from an editorial:

> Anybody may steal a safety device. We await a genius with some miraculous invention that will make flying safe. Meanwhile, one of America's leading commercial flying companies is using a very old device with brilliant success. There are no patents on it. Its cost is low. The name of it is carefulness.
>
> The annual report of a company that operates 27 flying-boats says that during the last year it has made 2125 flights and carried 9107 passengers, a total of 739,047 passenger-miles. This has been done without a single death or injury. Carefulness in inspections, in operation and in selecting men has produced a perfect safety-record for 3 consecutive years.

Again, in a recent issue of the *United States Air-Service Magazine,* we read:

> The record is 3 years of service without a single mishap; this is unparalleled in the history of aeronautics or any other method of transportation.

The record referred to is that of the Aeromarine Airways and has been made with flying-boats supposed to be surplus war-material. The types we have used are the F5L and the HS2. These were converted by building an enclosed cabin on the F5L and converting the HS2 into an open-cockpit boat.

Inducing the Public to Fly

We have found that the actual cost of operating these flying-boats, in regard to gasoline, oil, maintenance and depreciation, is as nothing when compared to the cost of selling aviation to the public and getting passengers down to an airport to fly. It is disheartening to go to a man of more than ordinary intelligence and beg him to go on a free flight; he will say "I prefer to keep one foot on the ground." That condition exists solely through ignorance. But thinking men and women usually see the light when they are presented with statistics showing that flying is safe; and it is safe.

We have an unfortunate situation here in that we are one of the few countries in the world that has no air-laws. We believe that defect will be remedied very shortly. In the meantime, we are not waiting for those air-laws. A few pioneers are going ahead and putting commercial aviation in America ahead of that of the rest of the world. Again I am speaking of flying-boats only.

If engineers designed a flying-boat which would go twice as fast as these we are operating, and our operating expense were cut 50 per cent, that would not help us to sell aviation to the public. The cost of getting the public to fly is the important thing. Many times people have told me that they have heard in general discussion that aircraft in America today are unsafe to fly in. Granted that many of them are unsafe when operated by irresponsible fliers, there are a few responsible companies operating good machines. We must let the public know in every way possible that we have commercial aviation now; not "when it comes" and "when we have a certain safe type of ship." We are flying safely now, every day.

The public does not want speed. The average speed of our flying-boats is from 65 to 90 m.p.h. That is enough for anybody. If you tell a man that you will fly him from New York City to Albany at 125 m.p.h., the chances are that he would not fly with you. The thought amazes him; he cannot comprehend flying at that speed. We know that a passenger is perfectly happy and comfortable in an enclosed cabin, even at 135 m.p.h., but the man in the street does not realize that. We who are engaged in commercial aviation are so "sold" on it ourselves that we do not get the viewpoint of the man in the street.

As stated, the general design of flying-boats is satisfactory today. I am referring to the F5L, the HS2, the two-passenger Curtiss Seagull and Aeromarine model 40. They will take care of the public demand, I believe, for the next 3 or 4 years. When the public is finally sold in general, it will be necessary to have 40 and 50-passenger ships. But it would be dangerous today to consider this possibility and not "boost" what we have already; because we would be wasting valuable time, Europe meantime going right ahead.

Influencing the Public

The public today is very easily influenced in regard to flying. We in the business can go to a man and tell him we would like him to fly and that it is wonderful to fly, with only slight effect. But if his neighbor goes to him and says, "I took a flight today," that creates the desire in his mind and he wants to fly. It is the human element. People do not want to be left behind. If some one else is doing a thing, we want to do it.

There is a great change in public sentiment as regards flying in this Country. We have noticed it in connection with railroads. When we started to operate flying-boats

[1] Advertising and sales manager, Aeromarine Airways, Inc., New York City.

3 years ago the railroad representatives said, "Well, it may come true, we hope it will, but we are not interested and you are taking up our time." But the New York Central Railroad Co. sent out a bulletin recently instructing its ticket-agents to furnish information on our flying-boat transportation, stating it is worthy of support. Many other railroads have followed suit. The Florida East Coast Railway Co., which operates the steamers between Key West and Havana, is distributing our literature, because we have shown that properly operated commercial flying is absolutely safe and a necessary adjunct to the railroads; it is not a competitor, but an adjunct.

If you go into the travel department of any bank in a big city in the United States and inquire about our flying-boat service, I think you will find that it will try to get you to fly. Why? Because the banks realize that the development of commercial aviation is today and will be the backbone of our national defence.

I urge you to get behind the pioneers who are putting aviation over now. We are bucking a hard game but we see the clouds breaking. We are carrying more people every day, and are making money with the present equipment. In commercial operations during the past year our company made money between Cleveland and Detroit on a pioneer service. Our boats fly between Cleveland and Detroit in 90 min. The trip takes 6 hr. by train; all night by steamer. We flew more than 4000 people in 2½ months. The first month, 49 per cent were women and children; the second month the passengers were mostly business men. Many of them have said to us, "You have proved that commercial aviation is here and we are going to boost it." They are boosting American aviation and I ask you to do the same thing.

THE DISCUSSION

JOHN P. TARBOX:—The fundamental feature of commercial-aviation success has not yet been touched upon. Must we rely upon the necessities of the Post Office Department, upon the goodness of Uncle Sam in standing a loss and upon the sporting blood of the public to get this industry to grow? Or must we rely upon the basic fact that we can offer to the public a traffic which it can use at a profit? Does not the root of the present high cost of getting people to use an airplane lie in the fact that, while people use it for the sensation, they, having had the sensation, do not care to go to the expense of a second sensation? We are forced in our advertising constantly to convince new people. We are doing the same work again and again. The success of the Aeromarine Airways, Inc., between Cleveland and Detroit is probably the most signal success that has been had. Perhaps that from Key West to Havana is in the same class, but it seems that people are using flying-boats between Cleveland and Detroit because they find that they can do so in their business at a profit.

Commercial-airplane design lends possibilities of giving to the public just that basic thing. Must we wait all these years to put this proposition over, or can we hope to do it through a vastly improved engine? Judging from what has been said here, only a small percentage of increase in profit would be sufficient. Suppose we had an engine that would develop from 10 to 20 per cent more power. Suppose we had a wing that was from 10 to 20 per cent more efficient, or, if not more efficient, that would give us a lower landing-speed and enable us to utilize to a larger extent those fields that are now available. Suppose we had safety-devices that not only would neutralize what is left of the backwardness of the public in boarding aircraft, but also counteract the effect of the untoward accidents that have come through carelessness. The public patronizes the devices at the amusement parks, the shoot-the-chutes and the loop-the-loop affairs, without the least bit of hesitation. Why? Because the crowds are doing it and because it is not over-expensive. Airplane flying is no more dangerous than that. Suppose someone produced a material that would give us a greater factor of safety, or enable us to reduce the weight of the airplane and thereby increase the useful load 10 or 15 or 20 per cent. Any one of these things or a dozen others might put the proposition over. I urge that we all look toward the improvement of the individual units of the airplane in the hope that such improvement will lend its share to general advancement of the business.

CHAIRMAN E. P. WARNER:—I am surprised that so many of the speakers have found the present airplane wholly satisfactory and have been disposed to neglect the advisability of any change, at least for the present. I am even more surprised at Mr. Blythe's statements regarding the inconvenience of traveling by air and his disposition to neglect altogether the question of safety as seemingly unimportant. The record that the Aeromarine Airways, Inc., has made is wonderful and is certainly worthy of the very highest praise; 740,000 passenger-miles without a fatality! The average in Europe has been only about 400,000 passenger-miles, although there are several lines that have run very much farther than that, some going well over 1,000,000. American railroads have an average record of about 70,000,000 passenger-miles per fatality. We must make still greater improvements in the safety of airplanes before we can expect people to ride in large numbers.

From people who have flown once and been asked to fly again and declined, and those who have not even been asked but made it known that they would not fly if they were asked, I learn that the thing that keeps them from flying is not the inconvenience, which is often very slight; it is the danger, or what they think to be the danger. They badly over-estimate the danger, to be sure, but that is what keeps them on the ground. In the summer of 1922 I talked with a number of the agents who are backing air transportation in London and Paris and, judging from what I heard, very much the same story can be told there as in this Country. They say that as soon as there is a sensational accident anywhere, even to a military machine, the bookings fall right off dead. After one such accident, the London-to-Paris airplane bookings dropped off about 50 per cent in 3 weeks. Very often a person comes in and engages passage, and comes back in about 2 days and wants to cancel it. Such people have been talking to their friends, who have all bidden them a fond farewell; they give up the hazardous adventure. That is the thing that is keeping people from flying. As for the inconvenience, the London-to-Paris line sends a luxurious automobile around for you and lands you by car at your hotel on the other end.

MR. TARBOX:—I agree with Professor Warner in regard to the necessity of safety. I think it is of extreme importance. There is no question that flying is safe when carefully done, but there is a great amount of carelessness, and everything that can be done, through the application of safety devices, the enactment of laws and the enforcement of regulations, would be of immense help.

Has anything startling been done in great-altitude flying abroad? What instruments do they use for night-flying and for flying in fog?

CHAIRMAN WARNER:—There has been no great-altitude commercial-flying abroad. Navigation at night and in

fog is not attempted. They do not endeavor to fly under conditions such as those encountered by the Air-Mail Service in this Country. One line, operating across Central Europe, probably comes closer to it than any other I asked one pilot how he navigated in low clouds and fog. He said he flew below the clouds. I said, "If the clouds or fog are only 500 ft. above the earth, what do you do?" He said, "We still stay below them." I said, "Suppose they are only 100 ft. above the earth?" He said, "We still stay below them." I had not the courage to follow him down any farther. On another line, which operates with perhaps a little larger percentage of passenger traffic, they did not attempt to go out if the report showed clouds lower than 1000 ft. high above any part of the course to be followed. As for night-flying, the only attempts that have been made under very carefully selected weather-conditions have been about four night-flights between London and Paris. All of them were made in moonlight and with seven lighthouses along the course. Night-flying on a large scale seems unlikely to be realized in Europe as soon as the Air-Mail Service will realize it in this country.

MR. TARBOX:—What proportion does the expense of obtaining business, which was mentioned as being so great, bear to the total expense?

H. A. BRUNO:—We include in that the hiring of personnel. It includes passenger men and the operating of offices, which all comes under the head of our general advertising expense. It is difficult to set a definite figure but, in different localities, it is likely to run anywhere from 30 to 60 per cent, which is pretty high.

In regard to the life of commercial flying-boats, we have one ship, the Santa Maria, which has been in service for 3 years; it has flown 54,000 miles. It is in first-class condition. We have changed the engines, of course.

We have only one reserve flying-boat in the Cleveland-Detroit service, in which we maintain double daily operation from both cities, leaving at 9 a. m. and at 4 p. m. We have had only two instances of leaving late. We have maintained a perfect record across Lake Erie of 222 crossings; we have had no forced landings and no mishaps. We credit our mechanics and pilots with that record.

EDWARD SCHILDHAUER:—How many forced landings has your company had in all its operations?

MR. BRUNO:—In our operations between Key West and Havana during 1921, seven flights that were attempted were not finished. Three of these cases were due to fog; the others were due to engine trouble. In one case the boat came down, was fixed and then went on. In two other cases we sent out another boat and carried the passengers on their journey. That was during the entire Southern season, which runs from Nov. 15 to March 15. In the New York City operations, we have had three forced landings and two delays from fog which is prevalent in the early spring. There were no forced landings on the Great Lakes Division in 1922. On the Miami-Nassau run there were no forced landings. It was made then three times a week, but this year we are maintaining a regular daily service between Miami and Nassau. So far, since Dec. 1, 1922, there has been a 100-per cent performance on all Southern routes.

R. R. BLYTHE:—I have been criticized for referring lightly to safety but, as a matter of fact, I believe safety is and must be first in everything. My thought was that we could not wait for round-table discussions on airplanes that will be built in the future; we must use, improve as much as we can and sell what we have. The Aeromarine Airways, Inc., has had no fatal casualty as yet; how long that record will continue is conjectural. The company conducts the safer form of airplane transportation, its boats operating over water. If we should say that our present machines are not safe, and that we must scrap them and build some that will be safe, we probably would eliminate all of the present activity. We must improve the present equipment, but we must use it and sell transportation in it meanwhile.

ARCHIBALD BLACK:—It has appeared to me, for the past several years, that our big problem has been that of convincing the banker that we can make aviation pay. The demonstrations of the Aeromarine Airways, Inc., during the past 2 years has accomplished more in this direction than all of our discussions. I think that the whole industry owes a debt of gratitude to the officials and the operating personnel of this firm for their most constructive work.

INTERNATIONAL AIR CONGRESS

THE 1923 International Air Congress, which will be held at London on the invitation of the British Government, will open on Monday, June 25, and close on the following Saturday. The principal object of the Congress is to give an opportunity for an international discussion of the various problems in connection with the design, construction and operation of aircraft. The papers to be read will be divided into four groups covering the following subjects:

(1) Aerodynamics
Airplane Construction
Research Methods

(2) Powerplants
Fuels
Lubrication
Propellers

(3) Air Transport and Navigation

(4) Personnel
Air Tactics and Strategy as Affecting Commercial Design
Airship Design and Construction

In addition to the sessions of the four groups, which will be held simultaneously, an opportunity will be afforded to visit various British aircraft establishments and factories. Also, the Air Ministry has arranged to hold the Royal Air Forces Pageant on June 30, the last day of the Congress.

Membership is open to nationals of all countries that are represented on the Federation Aeronautique Internationale or are signatories of the International Air Convention. Further particulars regarding the Congress can be secured from the general secretary, Lieut-Col. W. Lockwood Marsh, 7 Albemarle Street, London, W. 1.

Discussion of Papers at the Annual Meeting

THE discussion of the papers presented at the recent Annual Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum amount of effort.

In addition to discussion given below the discussion of Safety and Comfort as Inducements to Air Travel, by R. R. Blythe; Passenger Carrying Flying-Boat Operation, by H. A. Bruno; and A Critical Study of Modern Automotive Vehicle Steering Systems, by Herbert Chase is printed elsewhere in this issue of THE JOURNAL. The discussion of V. H. Gottschalk's paper entitled Society's Research Sheds New Light on Fuel Problem was printed in the February number of THE JOURNAL in connection with some supplementary data that were received too late for inclusion in the paper when it was printed in the January issue of THE JOURNAL. The discussions of the other papers, Testing of Leather Substitutes and Top Materials, by J. B. Davis; Aircraft-Engine Practice as Applied to Air-Cooled Passenger-Car Engines, by S. D. Heron; Experimental Survey of Gasoline and Kerosene Carburetion, by C. S. Kegerreis and G. A. Young; Cooling Capacity of Automobile Radiators, by E. H. Lockwood; Cheaper Closed-Body Construction, by George J. Mercer; Laws Governing Gaseous Detonation, by Thomas Midgley, Jr., and Robert Janeway; Needless Hardwood Lumber Waste, by Frederick F. Murray; and Automobile Finishing Varnish, by L. Valentine Pulsifer, will, it is expected, be published in the May issue of THE JOURNAL.

INTERNAL-COMBUSTION ENGINE CHARACTERISTICS UNDER HIGH COMPRESSION

BY J. H. HOLLOWAY, H. A. HUEBOTTER AND G. A. YOUNG

THIS paper is a report of a series of tests conducted during the summer of 1922 by the authors at the Engineering Experiment Station of Purdue University. The work consisted of research into the operation of internal-combustion engines under comparatively high compression on ordinary gasoline without detonation. The compression-ratio of the engine was 6.75 and the compression pressure was 122 lb. per sq. in., gage. The ingoing charge was passed through a hot-spot vaporizer and thence through a cooler between the carbureter and the valves. Jacket-water temperatures between 150 and 170 deg. fahr. were carried at the outlet port of the jacket.

The theory held by the authors as to the causes of detonation of the combustible charge is presented briefly. The source of the two phases of detonation encountered in this work is believed to be overheated areas in the combustion-chamber. The methods of combating these hot spots are given in detail, and the special equipment applied to the engine to accomplish the desired result is described. The effects of load, speed, compression-ratio and mixture-ratio are studied, and curves showing the variation in the engine characteristics due to each factor are submitted. All tests were run without a trace of detonation.

The results of the work point to the following conclusions:

(1) Automobile engines designed to give a uniform cooling of the combustion-chamber walls will permit the use of much higher compression-ratios than those employed at present, with a consequent gain in engine power and economy

(2) The fuel-air ratio for maximum economy borders upon the lean limit for reliable combustion

(3) For maximum power, the mixture-ratio need not exceed 0.075 lb. of gasoline per lb. of dry air

(4) With concentrated heating of the mixture at the carbureter outlet, a local temperature of 125 deg. fahr. is sufficient to give good operation at full throttle. Cooling to 100 deg. fahr. at the valves is desirable if the compression pressure of the engine is high. At part loads, a hot-spot temperature of 175 deg. fahr., with or without intermediate cooling, will give good results with lean mixtures

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THE DISCUSSION

THOMAS MIDGLEY, JR.:—A peculiar thing about the paper is that the type of fuel used in these tests is not described. I presume the authors are aware that compression pressures of 200 to 250 lb. per sq. in are possible, if the proper fuel is selected. I presume that commercial gasoline was used in these tests, but I want to emphasize that when engine tests are reported with respect to detonation we ought to make a complete story by including the characteristics of the fuel used; otherwise a paper will be absolutely useless in the future, for nobody will know what it is all about. If the fuel data are added, the paper becomes a permanent record of a real accomplishment.

To operate an engine on commercial gasoline at 122 lb. per sq. in. compression-pressure is certainly a real

achievement. The authors state that they believe this would not be feasible in actual practice, but every automotive engineer will serve himself and his product if he will do precisely the things that have been done at Purdue University in reducing the tendency to overheat the charge in the cylinder.

EDWARD D. THURSTON:—Will Mr. Holloway give the temperature and the proportions of the various fuels? It would be interesting to know how the point of best power and the point of best economy compare with the mixture that is chemically best.

SYDNEY G. TILDEN:—Will Mr. Holloway tell us his experience with regard to sensitiveness toward carbonization in operating at these high compression ratios? Is it necessary to clean out the carbon very often?

J. G. VINCENT:—In this paper a mass of experimental data that confirms the findings of many investigators along these lines is presented in a condensed form. In this instance, however, a serious attempt has been made not only to run-down the obstacles in the path of further progress but also to devise a means of overcoming them. I believe such practical efforts on the part of our University research men deserve the highest commendation.

It is to be noted that the results have been obtained with a four-cylinder knight-type engine and, although I believe the conclusions reached can be applied to other engines, I still think that in future work of this character similar data should be collected on up-to-date poppet-valve engines that are in the vast majority at present. In laboratory work of this character one is apt to lose sight of certain fundamental requirements of road operation. In mentioning certain of these factors I should like to go on record as stating that this discussion is offered in a constructive spirit and in the hope that some of these problems will be studied in the laboratory at greater length.

The prospect of using higher compression in automobile engines is a particularly alluring one in view of the handsome gain in power and the reduction in the fuel consumption to be attained in this manner. However, I have found that even when detonation is entirely suppressed and a high-compression engine, showing say 100 to 110 lb. per sq. in. gage compression, is driven on the road at ordinary speeds there is a distinct loss in smoothness of operation which cannot be overlooked. It is, of course, a well known fact that it is the compression-ratio, and not any particular compression-pressure, that largely determines the shape of the expansion curve. I judge, therefore, that the more rapid rise of the pressure in the high-compression engine is responsible for the loss of that smooth flow of power that we associate with up-to-date engines having more conservative compression-ratios.

Another disturbing element militating against the use of higher compression-ratios is the formation of carbon in the combustion-chamber. There is yet to be devised a lubricating system that will lubricate the cylinder walls adequately and yet not permit any oil to rise in the combustion-chamber. In other words, apparently, carbon troubles will always be with us and, no matter how well we cool the piston-heads, the spark-plugs and the exhaust-valves, carbon will gradually accumulate and detonation will follow. It has been my experience that if two cars are started out on the road, identical in every respect except that one has, say, 70 lb. per sq. in. compression, measured at about 120 r.p.m., and the other about 85 lb., and subject these two cars to the same driving conditions, the one with the higher compression will have to have the carbon removed about twice as often as the one with the lower compression. Viewed from this standpoint, it appears that the use of higher compression-ratios must await the commercial development of non-detonating fuels.

CHAIRMAN H. L. HORNING:—I suggest that Mr. Holloway take into consideration the part of Mr. Vincent's remarks that calls attention to the rough running when the engine was still short of detonation. That is a very important point and represents the zone of the factor of safety, we might say, that must be allowed below the compression-ratio that will run without the audible detonation that occurs and that is so disagreeable.

STANWOOD W. SPARROW:—Since many of us are working along very much the same lines, if Mr. Holloway would describe a few details such as the method by which he cooled the spark-plugs, it might be of convenience and save considerable time for other people who are trying to do the same sort of thing.

I think there has come to be a more general recognition of the importance of compression-pressure rather than compression-ratio. This was emphasized by Mr. Midgley at the 1922 Semi-Annual Meeting as well as just now by Mr. Holloway.

In regard to definition of terms used, the thing that has given the most trouble, in which the most improvement has been made by Mr. Holloway, is what seems to me to be more like preignition than what I term detonation. However, although it would be desirable if we could agree as to what should be termed *detonation* and what preignition, it is much more important that both be recognized as obstacles to the use of high compression.

S. D. HERON:—Complete elimination of detonation does not appear to be necessary with aircraft engines. The maximum output and a minimum fuel-consumption are usually obtainable only with intermittent detonation.

It is pointed out in the paper that much can be done to eliminate detonation by reducing the internal temperature of the cylinder-walls. Some recent investigations with aircraft-engine cylinders indicate that conditions exist where the above statement does not hold and that high cylinder-wall temperatures do not necessarily have such a deleterious effect on the performance as has been commonly supposed. The engineering division of the Air Service has been working with cast-iron air-cooled cylinders and has found it possible to obtain a high output with cylinder-wall temperatures hitherto considered impossible. With a 4½-in. bore and a 5½-in. stroke cylinder, using a mixture of 80 per cent aviation gasoline and 20 per cent of benzol as fuel, as much as 155 lb. per sq. in. indicated mean effective pressure has been obtained, with combustion-chamber-wall temperatures of over 700 deg. fahr. The combustion-chamber form appears to have a decided influence upon the wall temperatures that can be used without causing excessive detonation. The performance quoted above was obtained from a cylinder with overhead valves and an almost completely hemispherical combustion-chamber. Past experience with overhead-valve flat-head air-cooled cylinders has shown that combustion-chamber-wall temperatures of 700 deg. fahr. are productive of such violent detonation as to prevent continuous full-throttle operation.

PERCIVAL S. TICE:—The point raised about the shape of combustion-chambers has been very well taken. Will Mr. Holloway tell us what he can about the apparently direct effects of the mixture-temperature in this latter compression arrangement?

CHAIRMAN HORNING:—How does Mr. Holloway ac-

count for the low thermal-efficiency with a 6.5 compression-ratio? I calculated that he should get 34.4 per cent indicated thermal efficiency, but he obtained only 30.4 per cent. In other words, he lacks about 4 per cent of obtaining good performance.

J. H. HOLLOWAY:—The fuel used in all of these tests was Red Crown gasoline, such as we get in Indiana. The mixture-temperatures for good performance are given in conclusions 10 and 11. The mixture-ratios for best power at full throttle and for best economy at partial throttles are specified in conclusion 5. The chemically perfect mixture contains approximately 0.067 lb. of gasoline per pound of dry air.

We had a little carbon deposit in the combustion-chamber, the piston-head and the cylinder-head being the only available places for deposit. By running at from one-half to full-load most of the time, the carbon that formed seemed to curl up and chip off. We had very little carbon deposit with the proper mixture-ratio, but we did find that little particles of carbon that gave some trouble formed on the ports of the sleeves. That probably was, within a reasonable time, as we know it, for cleaning the carbon; not 2 or 3 days or a week. After a couple of months of running we would show up some color in that way, but we made it a practice never to clean the carbon off the cylinder-head or the piston-head.

We agree with Mr. Vincent that the poppet-valve engine offers a promising field for research along the lines of high compression. The ability to carry high compression-pressures seems to be purely a matter of keeping the exhaust-valves below the temperatures that will induce detonation. Careful water-jacketing of the valve-seats, small valves and multiple spark-plugs should make high pressures practicable in poppet-valve engines.

We might suggest that high compression-pressures with their attendant high explosion-pressures require an increase in the flywheel size to give a smoothness of operation comparable with that of a low-compression engine.

It is questionable whether high compression results in an increase in the rapidity of carbon formation. It is obvious, however, that the higher temperatures before ignition due to high compression will make an engine sensitive to carbon deposits.

The details of the spark-plug and the special head are illustrated in Fig. 2. The mica core and its gland are held by the steel shell that is shown in the upper left-hand corner. The lower end of this shell is screwed into the cylinder-head shown at the right of the illustration and replaces the standard spud that is cast integrally with the conventional cylinder-head and holds the top of the water-jacket in place. The water is in contact with the steel shell, which eliminates a threaded joint and a thickness of metal between the core and the jacket water, thereby facilitating the transfer of heat from the core. The question about the definition of detonation is rather a delicate one. Every one seems to have his own idea about it, and many of the ideas do not agree very well. It seems that we have two kinds of knock; that is, a knock that is like a "ping," and a knock, a dull heavy thud, that succeeds this ping when the spark is retarded. I do not know whether they are both caused by detonation. I am satisfied that the latter one is. It may be that the other is also, but it occurs at a different point on the stroke of the engine. For instance, if a detonation occurs from the hot-spot end of the cylinder, the explosion would occur well ahead of the dead-center in that case, or at some place ahead of the dead-center. If there is an early spark, the same sound is present. If the spark is retarded after a period of detonation, the sound seems to turn into this dull, heavy thud; so it is pretty hard to state, in my mind, just what detonation would be there. We have to distinguish between the two in some way.

Regarding Mr. Heron's question on wall temperatures, we always attempt to keep the wall temperature as low as possible; that is, consistent with the possibilities in practical operation. We run our outlet-water temperatures from around 170 to 190 deg. fahr., and the higher the wall temperature is, the sooner the engine apparently shows some detonation. We found also that whenever detonation starts from one cause or another, such as choked circulation or insufficient cooling, the power falls off very rapidly.

As to the effect of mixture temperature, raised by Mr. Tice, I think it is one of the most important features along this line. It seems to me that the detonation that occurs is dependent upon the initial temperature of the charge, of course, after the charge has gone through the process of combustion the temperature is raised; so that, the lower the start is of mixture temperature, consistent with good distribution, the less tendency there is to detonation. This is an important point in this problem.

I agree with Mr. Horning that the thermal efficiency at full throttle is low, due to the fact that the spark was given an advance of only 5 deg. The investigation was carried out to apply to automobile service and, since the major portion of the running was assumed to be done at partial throttle, the efficiency at full load was sacrificed in favor of the efficiency at part load. At three-fourths of full power the indicated relative efficiency based on the air-cycle is 60 per cent. I do not know on what basis Mr. Horning computed the efficiencies that should be obtained at the compression-ratio adopted.

O. C. BERRY:—How was the heat value of the fuel determined? I feel that I may be in error in my own work in using the higher heat-value of the gasoline. When we attempt to compare our thermal efficiencies with those reported by the English, we find that we make rather a poor showing, as their figures are based on the lower value.

I think it is important also to have an exact statement of how the friction horsepower has been obtained. I have been using three ways. One of them is by cutting out one cylinder at a time and subtracting the total horsepower on that basis from the horsepower of all the cylinders. This gives a very pleasing result because it makes it appear that there is almost no engine friction. Then, when the measurement is made by motoring the engine with the dynamometer, we are surprised to find at least twice the friction horsepower that we found previously. The most accurate method of measuring the friction probably is to use the balanced diaphragm meter, as designed at the Bureau of Standards. At any rate, in making a report of this kind, we ought to be very careful to bring out all this information, so that we may be able to interpret the results accurately.

MR. HOLLOWAY:—The heat value of the fuel we used was based on the lower rating; that is, 18,900 B.t.u. This value was given by the Standard Oil Co. The friction horsepower was obtained from the dynamometer by motoring the engine.

MR. MIDGLEY:—Red Crown gasoline is one thing in one place and another thing in another place. The brand "Red Crown" is not a specification for gasoline. In Indiana, we find that we will have a large sulphuric acid absorption where the Red Crown gasoline is pretty highly unsaturated. I would like to have a description of the

fuel, comprising the distillation curve, unsaturation, specific gravity and temperature of critical dissolution with aniline after being washed with sulphuric acid. Those four figures give a pretty fair criterion of what the compression value of the fuel is.

MR. TICE:—There seems to be confusion about the mixture-ratio statement. We all have the habit of speaking in terms of pounds of air per pound of fuel. All the literature includes that method of statement. Cannot the Society standardize on one thing or the other?

CHAIRMAN HORNING:—I, also, have had great difficulty in following the method of expressing the ratio of fuel weight to air weight. I think the English started, with the work of the Gaseous Explosions Committee, to express the ratio thus, 13-1, or the weight of the air to that of the fuel. So, when it comes to expressing it decimally, it is not clear to me.

What heat value, in British thermal units, is used when figuring the thermal efficiency? That is an important point because some of us are claiming some very high thermal-efficiencies. Our company figures on the basis of 19,400 B.t.u. We get somewhat over 20,000 B.t.u. in much of our fuel.

E. H. SHERBONDY:—In this connection, for the first tests in blast-furnace-gas work there is one value in natural gas and in the various artificial gases there are different heat-values, the rating always being on the basis of British thermal units per brake horsepower. I think that would be a very much more satisfactory basis for rating, than to rate on the basis of pounds.

CHAIRMAN HORNING:—Mr. Midgley, what heat value do you use for that Red Crown gasoline?

MR. MIDGLEY:—In round figures, 20,000 B.t.u. per lb. I feel that the actual value is the only value to use and that it really should be the lower heating-value. The arbitrary way of stating it at 20,000 B.t.u. or 19,400 B.t.u. or whatever value one may select, undoubtedly has been fairly satisfactory during the last 10 years, but we are looking forward to a period when benzol, alcohol and materials with different ratings per pound will come into use. We will not be able to standardize on those things nearly so readily in the future. For the future, we ought to look forward to the actual rather than an assumed value. We have used 20,000 B.t.u. just because it is a round number, and for no other reason.

CHESTER S. RICKER:—Is it not a question whether you are using the higher or the lower calorific value of the fuel? Is it not a question of whether you are considering that the by-products include water that goes away as steam?

PROF. W. E. LAY:—We have been using from 19,600 to 19,800 B.t.u. at the University of Michigan.

W. S. JAMES:—At the Bureau of Standards the lower heating-value has been used and usually it has been determined experimentally. The lower heating-values have been used because it is believed that the higher heating-value, including the latent heat of the steam that is formed during combustion, is an ideal figure that has no real significance in an engine of the type now used.

JOHN W. STACK:—We usually state the heat value at 19,400 B. t.u., as being the low value. The high value is sometimes 21,000 B.t.u.

H. S. MCDEWELL:—If a heat value for the fuel has not been assumed, that information is conveyed just as well by the fuel consumption. One is only misleading himself if he states a thermal efficiency on that basis. With the ordinary commercial gasoline about 20,500 B.t.u. is the high value. I believe in using the high rather than the low heat-value, because that is what is put into the engine.

MR. RICKER:—Valve-timing is not mentioned in the paper. You speak of compression-ratio, yet what does it really mean? You can move the compression up and down the horsepower curve so readily by changing valve-timing that, without a knowledge of the actual valve-timing of an engine, little is known about the compression and the effective pressures in the combustion-chamber.

MR. HOLLOWAY:—The valve-timing used was the standard timing of the Willys-Knight engine.

CHAIRMAN HORNING:—We have demonstrated that there are a number of different heat-values in British thermal units used for fuel; it is a subject that the Society and the Research Committee could well take up. It is very important to know exactly the value of the fuel and the correct lower-value when making scientific investigations of an engine. It is very serious, for instance, if an Englishman or a Frenchman says that he gets a 33-per cent indicated thermal efficiency, for him to be figuring on one basis and for us to be figuring on another. We simply cannot compare the readings. I have found it very difficult, in getting the relative efficiency, where comparing with the other fellow.

A. A. BULL:—Referring to the report of the tests conducted with high compression, the first impression is the apparent ease with which satisfactory operation without detonation was obtained. There are some interesting disclosures, however. In propounding the theory of detonation, it is stated that "unless the heat, due to this latter compression, is transferred to the combustion-chamber walls as rapidly as it is generated, the temperature of the entire mass of the gas rises to the ignition point and explodes instantaneously." Surely, this needs some qualification, as the heat-loss, if this were true, would greatly reduce the effective work done in expansion. This condition, however, introduces the question as to what influence the stroke-bore ratio has on the expansion characteristics and its effect on detonation.

In summarizing the salient features that permit carrying high compression, reference is made to the necessity for comparatively cool exhaust-valves. It is unfortunate that actual temperatures in the engine under investigation were not obtained, so that the limit to which these temperatures can run could be determined. In this connection the factors that affect the exhaust-valve temperature, the valve-timing, the seat width and the proper cooling of the seat, should certainly receive strict attention if the valves exercise such a distinct influence on high compression.

The necessity for aluminum pistons in place of those made of gray iron is, of course, in accord with prevailing general opinion, except that the benefits are minimized considerably by the presence of carbon in actual service.

It has been our experience that higher mixture-temperatures do influence detonation; but, on the other hand, instances have occurred where abnormal heating actually has reduced the tendency to knock. It appears to be essential that heat control be provided in proportion to the throttle opening, limiting the temperature under open-throttle conditions.

It is interesting to observe the results obtained by the use of the sleeve-valve engine, which seem to indicate that the higher valve-temperatures do have a decided bearing. Perhaps the most significant portion of the results is the reference to the spark-advance at full load, but it is not clear whether the spark-advance of 5 deg. at full load was the maximum that could be used to avoid detona-

tion, or the spark-advance that was necessary to obtain the maximum power. Unquestionably, the spark-advance has a very decided influence, the importance of which is perhaps not generally recognized, particularly on heavy-duty engines. In this connection the combustion-chamber design had a distinct bearing; for instance, it happens frequently that the spark-advance required for the maximum power is in the zone of detonation, and a reduction in the spark-advance away from the zone of detonation reduces the power. I have in mind some experiments conducted along this line, clearly showing the possibility of having a considerable range between the spark-advance that would produce detonation and the reduction in the spark-advance that was possible without reducing the power. This range was between 24 and 14 deg. at 1000 r.p.m. The control of the spark-advance, in proportion to the throttle opening, is worthy of more consideration. It is true that the higher compressions that provide better combustion conditions make it unnecessary to have the ignition point so far ahead of the upper center as is usually necessary, and the combination of the two factors increases but very little the tendency to knock. The influence of high compression under actual operating conditions must be taken into consideration. The presence of carbon, which is more or less inevitable, and many other factors, prohibit the use of compressions that, from a theoretical standpoint, are ideal. Some control can be exercised over this, however, by arranging a compression curve properly, so that the lower compressions exist at the lower speeds, under which conditions the knock is most pronounced.

MR. HOLLOWAY:—The factor that apparently has a decided influence on detonation is the manner in which combustion proceeds after inflammation has been started by the electric spark. If the reaction is carried to completion by the normal propagation of the flame-front, no detonation will occur. If the entire charge in the combustion-chamber reaches the ignition temperature simultaneously, however, the explosion-pressure will be terrific. The logical method of maintaining normal combustion conditions is to prevent a rise in the temperature to the point at which the action is instantaneous. The effect of the combustion of the initial portion of the charge is to compress all of the unburned gas and in that way to raise its temperature. One way to limit this temperature-rise is to provide an avenue for the dissipation of the heat in the gas and thus to give no chance for detonation. A path for the escape of sufficient heat to prevent detonation would not necessarily involve an appreciable increase in the radiation loss during the expansion stroke. With the high temperatures of the burned gas, the change in the cylinder-wall temperatures required to affect the rate of heat-transfer noticeably would be much greater than that necessary to overcome detonation.

TESTING FUELS FOR HIGH-COMPRESSION ENGINES

BY STEPHEN M. LEE AND STANWOOD W. SPARROW

THIS paper is concerned with certain of the methods used and results obtained in two investigations of fuels for high-compression aviation engines. The fuels in question are benzol and ethyl alcohol, either alone or as blended with gasoline.

The necessity of mixture-ratio runs in fuel investigations is vigorously emphasized. In that the tendencies of a fuel to detonate or preignite limit the conditions under which it may be used, methods of estimating these characteristics are discussed. Also a graphical representation has been made to illustrate the relation between compression pressure, compression-ratio, volumetric efficiency and indicated power in order that, with a given engine, the effect on detonation of changing engine conditions may be estimated.

Results characterizing the performance of the different fuels are mentioned and particular attention is directed to cases where these results are in contrast with current opinion. [Printed in the January, 1923, issue of THE JOURNAL.]

THE DISCUSSION

E. H. SHERBONDY:—What is the heat-value of benzol?

STEPHEN M. LEE:—The heat-value of motor benzol was taken at 17,300 B.t.u. per lb., the lower heat-value.

CHESTER S. RICKER:—Some controversy has arisen in regard to the bad effect on the life of the valves, of burning benzol in an ordinary engine. What experience have you had in this regard?

MR. LEE:—When using the blended fuels and high ratios the valves were not found to be any more burnt or worn than with gasoline at the lower ratios.

MR. LIPTON:—Fig. 7 of the paper shows volumetric efficiency. What temperatures were indicated in the intake-manifold?

MR. LEE:—The air temperature at the entrance to the carbureter of the one-cylinder engine was maintained constant at 30 deg. cent. (86 deg. fahr.). The intake-manifold temperature was not taken.

CHAIRMAN H. L. HORNING:—It is evident that we can run at much higher compression than we are using at present.

MR. SHERBONDY:—In connection with these tests, a point not very generally appreciated relates to the fuel consumption and the thermal efficiency where a constant pressure enters. We have all heard about the wonderful efficiency of Diesel engines, and these tests bear out the theory that the fuel consumption of the constant-volume engine can be much lower than that of the constant-pressure engine. The idea seems to be very prevalent among engineers the world over that the constant-pressure cycle is more efficient than the constant-volume. This is not borne out by actual tests. Recently, I witnessed a test of a good-sized Diesel engine. It was rated at 135 hp. and weighed about 250 lb. per b. hp. The builders thought they had a very light, very efficient engine. The fuel consumption was about 0.58 lb.

MR. LEE:—The efficiency of an engine operating on either the constant-pressure (Diesel) cycle or the constant-volume (Otto) cycle depends upon the expansion-ratio. Usually the expansion-ratio of a constant-pressure engine is higher than that of a constant-volume engine. The purpose of this work is to make possible an increase in the expansion-ratio of engines operating on the constant-volume cycle. I would like to ask Mr. Sherbondy whether the fuel-consumption figure he quoted for the Diesel engine was per brake-horsepower hour or per indicated-horsepower hour?

MR. SHERBONDY:—Per indicated-horsepower hour.

THOMAS MIDGLEY, JR.:—A member of a firm of Diesel

engine builders in Germany, who is a high-grade engineer, showed me the results of an experiment conducted on an automotive-size Diesel engine, giving 0.68 lb. per hp-hr. at one-quarter torque; I showed him the tests of a 7-to-1 compression-ratio, Chevrolet engine that gave 0.67 lb. per hp-hr., and he acknowledged that such results, with the knock eliminated, meant that there is only a very limited field for the Diesel engine in automotive work.

W. S. JAMES:—Regarding the relative efficiency of the constant-pressure and the constant-volume cycles, the efficiency of the constant-volume cycle is dependent upon the volumetric expansion-ratio. In the constant-pressure cycle the efficiency is dependent upon the expansion-ratio at the time when expansion begins. The Diesel engine may therefore be inherently handicapped by the fact that a significant interval of time is required to ignite and burn the fuel before the actual expansion starts.

CHAIRMAN HORNING:—That is an excellent distinction. I will read some fuel-consumption figures in pounds per indicated-horsepower-hour taken from an engine that has been on the road for 3 months and was found satisfactory by the driver for accelerating power and the like. At 600 r.p.m., 0.487 lb. per i. hp-hr.; at 800 r.p.m., 0.474 lb.; at 1000 r.p.m., 0.463 lb.; at 1200 r.p.m., 0.450 lb.; at 1400 r.p.m., 0.440 lb.; and at 1600 r.p.m., 0.430 lb. When we showed that to a Diesel-engine man, he collapsed.

S. W. SPARROW:—In regard to roughness of operation with the high-compression engine, the engine ran as smoothly and with no more vibration at the 14 to 1 compression-ratio as it did at the low compression-ratio. If high-compression engines have shown this roughness, it probably has been a case of preignition that was not pronounced enough to diminish the power seriously, and yet was not audible as detonation. That is very much the thing that Mr. Holloway has been working to eliminate. Such preignition may make an engine operate very roughly although with only a small decrease in power and with no audible detonation.

MR. MIDGLEY:—This matter of roughness is a bugaboo. We made a mistake when putting up a high-compression engine. We planned to make the ratio 7 to 1, but we found we had to leave an extra 1/16 in. on top of the piston and this gave a 225-lb. per sq. in. compression. That machine is being driven every day and has been driven for 10 months and is entirely satisfactory. There is no roughness; it is just as smooth as an engine is normally. I drove a Chevrolet car having a 160-lb. per sq. in. compression-pressure one summer; there is no roughness.

MR. SHERBONDY:—One practical point in connection with detonation is cylinder construction. Loose-head engines are fairly common now, but the great disadvantage of a loose-head engine is the very high charge-temperature that attends its use. I believe it is impossible to get anything like the mean effective pressure with the loose-head engine that can be obtained with the other type. Another problem is that of thin versus thick cylinders.

MR. RICKER:—On an engine with which I was experimenting we increased the compression about 25 or 30 lb. per sq. in. and experienced the roughness that J. G. Vincent mentions. A little later, we ran the same engine with different manifolds that were designed to give more uniform distribution and the roughness was gone.

CHAIRMAN HORNING:—One of the ways of telling where you are wrong is to listen for detonation in the various cylinders and find out whether the manifolds are wrong as to distribution and so find out which cylinder is getting the most charge. In a very recent test, the best fuel-consumption was 0.510 per b. hp-hr., but, by modifying the manifold, it went down to 0.485 lb. That was all that was done. It really should have been 0.440 lb. The difference between 0.440 and 0.485 lb. per b. hp-hr. was chargeable almost entirely to distribution.

IMMEDIATE POSSIBILITIES OF COMMERCIAL AIRPLANE SERVICE

BY C. G. PETERSON

STATING that the heretofore impassable barriers to commercial aviation have been costs and the lack of desire of the public to fly often, or to fly at all, the author proposes that the public, which must constitute the market for airplanes on a commercial basis, be educated by a demonstration of safe and reliable payload airplane-service extended over an indefinite period, and outlines a plan that includes the surmounting of cost deterrents.

He marshals arguments and statistics to show that such a public demonstration can be made by a proper and adequate equipment, operation and maintenance of the Aerial Mail Service, since it has been demonstrated already by this service that mail can be carried safely by air and that it can be flown through hard Northern winter weather. His statistics include a consideration of the present volume of mail, special-delivery-letter and parcel or package-carrying possibilities as revenue producers, being inclusive also of the postal rates necessary under such conditions.

An estimate on the cost of equipping and operating a night-flying line between New York City and Chicago, based on present equipment, is given. The author believes that passenger traffic would follow unsolicited just as soon as the public realized that the mail airplanes were flying safely and on time. [Printed in the March, 1923, issue of THE JOURNAL.]

THE DISCUSSION

C. G. PETERSON:—We will need the support of every one in the aeronautical industry when the time really comes to influence Congress. The bill that will be required can be written in 10 lines. All that is needed is for Congress to authorize the Postmaster General to let contracts for carrying mail. If such a bill is passed, the appropriation will follow. It need not be large. As soon as real commercial aviation comes through at carrying the mail, we can expect the public to start flying consistently right after that.

CHARLES M. MANLY:—The important thing that we must do for aviation is to find work for it. The remarks of the speakers have all tended toward this one big and important point of keeping the industry going and finding means of keeping it going. The thing that keeps all industries going is selling the goods. The situation in connection with aviation is that we must find susceptible customers and build up a business by selling what we have. Mr. Peterson has pointed to mail service as being a very important line to sell, and I think this is one of the things that we should work on to create a strong favorable sentiment. If we could show the farmer how this would benefit him, we would get appropriations at

once. If we can show him that air-mail service brings him nearer to the city, we can get an appropriation, even if it involves a loss to the Post Office Department. To get the farmer's mail to him quicker, or take something that he wants to him, will help to sell commercial aviation. We must cudgel our brains to sell this proposition. I feel less downcast over the situation than many probably do, because I have passed through still worse stages of it.

Aviation will go on, but if we are to build up an industry we must sell what we have and not sit around and simply wish and hope. The big thing is to keep hammering on the proposition of selling mail service here, overwater transportation from Florida, Detroit, Cleveland and other places, thus getting the cumulative effect of it all and in that way building up the business.

Mr. Peterson also mentioned that no airplanes have been produced and sold for commercial purposes at a profit that were complete new machines. That is a serious situation; however, it is partly tied up with the fact that production is not yet great enough to justify quantity-production methods. Also, many of the things that we have to use are very expensive anyhow, and possibly economics enters in that we have a quantity of equipment that was built during the war and it is natural to keep on trying to use it to reduce the expense.

There are many places where aviation can be used, however, if more of us will give our time to trying to sell the thing and fewer of us try to invent new machines and improve some theoretical design. The big thing today is to sell aviation and to sell the Government on the idea that it must build up its military power through having the factory facilities and having these designs worked out completely. There is no excuse today for our military services being in such a situation that they cannot immediately pull the blueprints out of the files and order machines built according to them. We ought to have learned our lesson from the last war on that. The most expensive thing we had was delay. So, we must sell the military side as well as the Post Office Department. Then we must sell aviation in all these other applications, such as carrying passengers, light express matter and the like. We must utilize the places where we have the greatest chance to make the best showing on the economics of it.

C. D. HANSCOM:—I was rather surprised when Mr. Peterson brought out the fact that it only takes 1 cent per letter to carry the mail. I had suposed it was 1½ cents. If my figures are correct, his estimate of 200,000,000 letters per year would give something like 13,000 lb. per day and, with that amount of mail, I think that his figure can be beaten. I think that we can carry a letter for 0.8 cent from New York City to Chicago, terminal to terminal; that is, without profit. For 1 cent, which is the amount that is left after the Government gets through, we would have a reasonable profit included. I think that we actually can make a commercial proposition of the mail under those conditions now. Certainly we should be able to with the additional express and special service that would be available.

LEE D. WARRENDER:—Regarding the need of educating the public, last fall when the races were on a blimp burnt up down in Texas and there were big, flaring headlines across the tops of the newspapers. When I went into an engineer's club, a practical engineer said: "Is that one of the machines that made the speed record last week?" If that is the extent of ignorance among people who should know better, public education is a very serious problem and is a momentous one to tackle and handle.

Regarding noise, I was making a flight from Dayton to the City of Washington in one of the Martin bombing airplanes and I became tired and went to sleep riding in the front cockpit; I was asleep for at least 1 hr. right between the two engines. I did the same thing going from Indianapolis to Dayton, flying in a Liberty. If one person can be educated to be able to sleep in an airplane, the same thing can be done with the public.

Practically everybody here seems to be afraid of metal construction. They speak of it and pass it by. I think they are afraid because, in the past, most of the airplanes have been made out of wood. They know wood; it is easy to work and they do not go to people who have had experience in metal construction; they will put some man who has never had any experience with metal construction in charge of all that work.

With regard to the comparative operation of wood-working and metal-working machinery, the former is built to work with limits of ± 1/64 in., and metal-working machinery is built to operate with limits of ± 0.0001 in., which gives a comparison of the quality of the machinery and the type of work that it can do.

EDWARD SCHILDHAUER:—To follow out Mr. Manly's argument, we must get to the farmer, because he is in the majority. There is no greater farming section than the Middle West. The finest landing-fields are there because it is a prairie. What the farmer in the Middle West wants is goods and mail from the East; he is interested in what is coming from a long distance.

It is not necessary that aeronautics be subsidized by the Government, or to go to the Government and ask for favors. If the aeronautic industry will layout a plan of action such as I propose, I believe that it can be put across by the business men of the Country because they will demand expansion. It is a fact that goods delivered by overnight trains can be delivered during the following forenoon by airplanes and advance the time of delivery. It is also a fact that airplanes cannot compete with trains that deliver goods produced at the starting point of the airplane because the trains have the advantage of the night schedule. The goods must come from a ride overnight to that point, and the airplane must start out in the morning. Airplanes cannot compete with trains unless they fly by night, and we have not yet arrived at the period in the expansion of airplane usage that enables an airplane to fly at night. I do not pose as an authority; but I have read about night-flying by airplanes, and night-flying of airplanes in fogs and landing in fogs. It is the consensus of opinion today that an airplane cannot land in a fog on a commercial basis; neither can it fly by night on a commercial basis unless the airplane route is laid out so that there is a landing-field that it can glide to, and this landing-field is ready and free of fog when the airplane wants to use it.

I propose that, since the goods to be delivered by airplane should have night travel to save time, a backbone-service of airships be established between New York City and Chicago, the airship to leave New York City at night and arrive in Chicago at dawn. From the same field, airplanes would then distribute to St. Louis, Kansas City, Omaha, Sioux City, St. Paul, Superior, Green Bay, Milwaukee and to the cities within that entire area. In the afternoon, additional airplanes would start from those points that are say 400 miles distant, and come to Chicago bringing the banking papers, the mail and other express matter that goes East. At night, the airships would leave Chicago and land in New York City and distribute there the next morning. This would provide a

backbone-service with an auxiliary service stretching out for the business. When we establish a service that will make a Chicago or a St. Paul man realize that goods purchased in New York today can be received by him tomorrow before noon, he would not care whether he paid 15, 20 or 30 cents per lb. for such quick delivery. That is not true for all goods, but I say that it is true for special goods. Out of the 400-odd carloads of express matter that originates in this metropolitan district daily, we may expect that from 50 to 60 carloads will go to Chicago and the Chicago gateway. Even at 10,000 lb. per carload, and a carload is usually 20,000 lb., one can calculate how much special material there should be in that mass of stuff to provide a load for airships. With an airship, we could transport one or two carloads readily; and, I dare say, when that service has been established, the business would come to it. The experience of the express companies has been that whenever they have established a faster route, business has traveled that route. The American Railway Express Co. will verify the fact that business will follow the route of the greatest speed. By the plan that I propose, we will get speed and get the airplane transportation where it belongs, as a feeder for the airship.

CHAIRMAN E. P. WARNER: — Mr. Peterson specified, when giving his figures for the New York City to Chicago air-mail line, that four airplanes would run each way each night and that there would be a total of 60 planes in service, with a 1000-hr. life for each airplane. It seems to me that this is a very excessive reserve. If we have to have a reserve of 650 per cent, the airplane is not good enough for commercial service at present; 200 per cent should be an ample reserve. An airplane life of 1000 hr. is not satisfactory; we ought to get a 3000-hr. life at least, and I think we can get that now, as a matter of fact, under proper conditions. That is the very minimum that should be considered for commercial operation.

We cannot depend on commercial operation to keep the aircraft industry alive even under a subsidy until it is tremendously magnified beyond anything that at present exists either here or abroad. Mr. Peterson's figures called for only 20 new airplanes per year on this New York City-Chicago route, and I think his figures are very liberal in that respect. According to the best figures that I could secure, the French Government is purchasing about 1500 airplanes per year at present for military purposes. It is subsidizing commercial air-lines. The French air-lines are taking about 60 to 75 airplanes per year, about one-twentieth of the military demand. The French factories are going ahead. I visited several factories and each of them is employing more than 1000 men on military-aircraft work at present. The question of the upkeep of the industry should be kept wholly separate from that of operation for the present. We cannot look to the commercial operating firm to keep the industry alive.

MR. PETERSON:—I cannot attempt to go into all the figures that I used in working out those estimates, in a short discussion such as this. I figured on 60 airplanes, keeping four in the air each way; a total of eight for the round trip. They would be operated on divisions the same as is done on the railroads. I would not attempt to fly one airplane straight through from New York City to Chicago. Figuring on three divisions, there would be 24 airplanes in the air per day; so the percentage in reserve is only a little over 200.

Mr. Schildhauer's idea is to establish first an airship route from New York City to Chicago. There is no doubt at all that, on long hauls, airships would eventually be cheaper and better than airplanes. The point is that in establishing an airplane route, we have the airplanes to begin with and can get the fields. For the establishment of such service, $2,000,000 is not an excessive sum; it is exceedingly small. But to establish an airship line, $2,000,000 is only a drop in the bucket. As to the airplane being used for radiating and furthering airship flights, that, of course, is one of the developments that is bound to come; but it seems to me it would be very disadavantageous to attempt to go as far at present as to ask support and subscriptions from the public for a vast airship line to operate between those two cities.

MILITARY-AIRPLANE DEVELOPMENT AND CONSTRUCTION IN PEACETIME

BY F. H. RUSSELL

THE reconstruction period since the war has served to establish aviation as an essential arm of both the military and the naval forces of the Government. This in itself is a real accomplishment. But for several reasons the airplane industry has not performed the service that was expected of it and has not received the support that is necessary for its existence. Although the expense is great, the development of aviation through the facilities at McCook Field and at the Naval Aircraft Factory has been hampered by red-tape and by the fact that the personnel of the Government agencies are at the same time the judges of new developments and the competitors of the engineers in the industry. The result is a feeling of reticence among civilian engineers with regard to disclosing and developing new ideas, the retarding of the advancement of service types, and slow deliveries. Although several companies at the close of the war were well equipped to produce airplanes cheaply and efficiently, these gradually have been driven out of existence and their places have been taken by smaller organizations that depend solely on casual orders which return small profits.

Competitive bidding has resulted in delay to the Government and loss to the manufacturer; in some instances bids have been asked on machines that had not been sufficiently developed to allow the Government to furnish blueprints, design data or a bill of material. The safety of the Nation is predicated on a dependable source of supply of equipment, especially aircraft. An important function of the Government, therefore, is to see that the engineering and production data are complete, uptodate and practical. This is not usually the case, the contractor being depended upon to complete and correct the data; and an unforeseen loss of time and money has been entailed. Early development of the art of aviation was due to the genius of a few men, but the development of the future will be by organization, with specialists in every line; the production of the world's fastest airplane at the races in Detroit is a case in point. Confusion has arisen through the custom of ordering new types in small quantities and of depending on competitive bidding for the further supply, on the assumption that when once completed the article was "commercial" and not proprietary.

The suggestion is made that the experimental work and the subsequent developments be confined to the same organization, with provision for production in large quantities in time of war. The Government's problem should be the selecting of airplanes for training and operating, and the guiding of the industry in developing such designs. Engineering and production should go hand-in-hand. Government subsidies, such as are customary in other countries, are not needed yet but production must be encouraged through the supply of Government equipment. Particular types of airplane should be considered proprietary, but the Government should be free to purchase any design at any time in any stage of advancement and place it by competition or assignment with recognized units in the industry.

Cross-licensing, originated as a war concession by patent owners, has had the effect of causing some persons to feel that any airplane should be purchased by open competitive bidding. But this agreement did not contemplate encouraging one manufacturer to use another's design or standardizing construction so that it could be used by all. Competitive bidding should be used only when a producer has been found incompetent or unwilling to furnish his product at a reasonable price under reasonable conditions. Considering each type of airplane as proprietary would make for permanence of business, encourage small companies to increase their facilities and guarantee to the Government a source of supply in time of peace and the distribution of data and personnel in time of national need. [Printed in the March, 1923, issue of THE JOURNAL.]

THE DISCUSSION

EDWARD WALLACE:—To correct an impression that has been given, I believe that the Government receives drawings from which it can build aircraft during wartime emergency. I believe that the Government has been supplied with drawings, specifications, bills of material and parts so complete and so accurate that if war should break out, it could produce aircraft in any quantity that it desired by subletting the various units of the machine to firms in various sections of the Country. I know of a company that designed and produced 20 machines in less than 12 months from the day they were started. The machines were accepted by the Air Service. Those drawings are now on file in the engineering division of the Army Air Service. The War Department also has special drawings for the Liberty-engined and other airplanes it is listing so as to be able to produce them. I say this in defence of the Air Service, which is doing very efficient work. Its bills of material are very efficient, although it may not be the privilege of every one to have come in contact with these bills of material.

When engineers concentrate to the extent that they should in refining fittings and using the materials of construction properly, such as distributing the material in its proper place, using it where it is most needed and making airplanes within the weights specified, we can gain the confidence of the public and of the Government and prove that we can actually build the planes as they are required. The thing that engineering societies and professional men should concentrate upon is actually to produce the goods. When that is accomplished, the people will believe that aeronautics is an accurate science. There is nothing very difficult about the structure of an airplane, although there are many things to learn. It requires only common-sense, persistence and concentration, so that nothing shall be overlooked.

Inspection is very important. An airplane must be complete as a whole, for one weak point may result in a crash. There is a possibility that, in the rush of things, these important factors in constructing airplanes will be overlooked and so cause adverse public opinion.

Recently, I saw a catapult about 50 ft. long that will throw a large airplane into the air so that it can fly off at a speed of about 60 m.p.h. If people can see airplanes shot into the air from the tops of post office buildings and flying off safely, then we shall see a change in public opinion.

In defence of the Post Office Department, I will say that its airplanes have flown more than 1,000,000 miles without any trouble. The department is actually building some of its own airplanes to carry 800 lb. of mail and is doing it very efficiently. Thus it has developed trained workmen who know how to build the airplanes and inpect them properly.

A. KLEMIN:—Is it not possible that we are all hanging too much onto the skirts of the Government? The Air-Mail Service and the Army have been suggested as aids, but we want the public to help us; we want the public to become interested and sold on aviation. Could we not do more by selling aviation on an industrial basis? I have in mind selling aviation in the way, for instance, that the Loening Aircraft Corporation is selling it. This company has a well-defined policy of selling a high-grade product at, perhaps, a seemingly very high price; but it follows up the sale by insisting on excellent pilots and on excellent service organization and by giving, I believe, very good service to its customers. The company sells to sportsmen. The fact is that this company sells airplanes, at something like $20,000 each, to people who have no accidents, are apparently satisfied and are likely to be repeat customers. Let us sell the airplane as a sporting proposition in the way that it should be sold, independently of all Government support.

In selling the airplane on an industrial basis, I believe that any business man in the United States can be interested in aviation. Let us go to certain specific industries and show them that the airplane can be used for a definite commercial purpose. For instance, I have been associated with some people in selling a man an airplane in which he is going to go from one lobster fishery to another to perform his tour of inspection rapidly and efficiently. He figured that he would save money in that way, and that was the great point to bring home to him.

A company in New York City is selling photographic service and it is doing a large volume of business. In all the great cities of the United States, photographic companies are already in existence to which the airplane might be sold for this specific purpose. Paper manufacturers own vast forests. We can go to them and explain how they can safeguard their forests by the use of airplanes. We can point out how much an airplane will cost, how it can be used and how to get pilots. Such industries will buy airplanes and use them as they are being used in Canada today, where one particular company has 25 forest-patrol airplanes in operation. If we go right through the industries and use a little real salesmanship in the way that the motor-car people have done, we may get there.

FRANK H. RUSSELL:—I want to get some information from Mr. Wallace for the advantage of those who may not have it. First, were the drawings, specifications or bills of material that he speaks of guaranteed by the United States Government for the building of those 20 machines? Second, were the 20 machines built by another than the original producer or designer?

MR. WALLACE:—The original machines to which I re-

ferred were Martin bombing airplanes. Work was begun on July 1 and the 20 machines were finished June 15 of the following year. I know that about 100 typographical errors and mistakes in the specifications have been corrected and reported to the Air Service. It is very difficult at times for a company to fall in line with another company's limits. The Government saw the necessity of having certain limits and making all fits free, so that the parts could go together if made in different sections of the country.

MR. RUSSELL:—Did the United States Government guarantee those drawings?

MR. WALLACE:—I do not think that the Government or the Air Service could guarantee another company's drawings.

MR. RUSSELL:—Did it offer them to the industry for public bidding without making any guarantee as to their accuracy?

MR. WALLACE:—I do not think it could guarantee the drawings for it had not proved them. The only way it could prove them was to let another company use them. It might eventually guarantee them after that.

MR. RUSSELL:—On the contrary, the Government did so offer the drawings. The machines were produced by the original designer as a proprietary article and very successfully; but when the drawings were put into another factory without the guarantee of the Government on a public bid, the first company building that machine spent $50,000 on engineering work before it completed the first airplane. Mr. Wallace has confirmed rather than contradicted my statements. The Martin bombing airplanes were offered to public bid, contracts were placed and the contractors assumed an unknown risk. The Martin bombing airplane was considered a commercial article and yet the Government itself could not vouch for the drawings from which it was constructed.

MR. WALLACE:—It is necessary to note the following to understand the expense of $50,000. The company had a contract for 50 machines. Many alterations of design were involved that may have cost the builder much more than it would have cost the other company that produced the drawings of the original machines.

THE DESIGN OF COMMERCIAL AIRPLANES

BY E. P. WARNER

THE author discusses commercial-airplane design in general terms, considering the subject under the main divisions of economy, safety, speed and comfort. Under economy, mention is made of possible reductions of first cost by designing for long life and reliability, the effect of the former on the depreciation allowance being obviously advantageous. Airplane size is debated also, the trend of progress being seemingly toward the giant airplane.

Safety is stated to be dependent upon reliability, structural strength, stability, control, fire prevention and reduction of risk of injury to passengers in the event of a crash. Minimizing the results of a crash is considered suggestively.

Speed is governed almost solely by the ratio of wing loading to power loading; hence, speed will always be kept as low as possible without loss of business to competing transportation enterprises. Among desirable measures to secure comfort, adequate ventilation and the elimination of noise are included. [Printed in the February, 1923, issue of THE JOURNAL.]

THE DISCUSSION

ARCHIBALD BLACK:—Commercial aviation is a subject to which I have given fully half of my time during the past 3 years. Consequently, I have followed Professor Warner's paper with great interest and feel that he has shown a very clear appreciation of the problem of airplane design in all of its details.

The problem of economical operation, which also includes that of safe operation, is the one outstanding point in design considerations. It appears inadvisable to count upon subsidies other than payment for carrying mail, at least in the United States. In this connection the specifications attached to some foreign subsidies might prove very misleading as regards the requirements of commercial airplanes. Some of the French specifications, particularly, suggested the intention of overnight conversion of supposedly commercial airplanes into military use.

As to the matter of speed, I am in general agreement with Professor Warner's remarks, but consider his suggestion of 85 m.p.h. rather low. In my paper entitled The Influence of Design on the Cost of Operating Air-

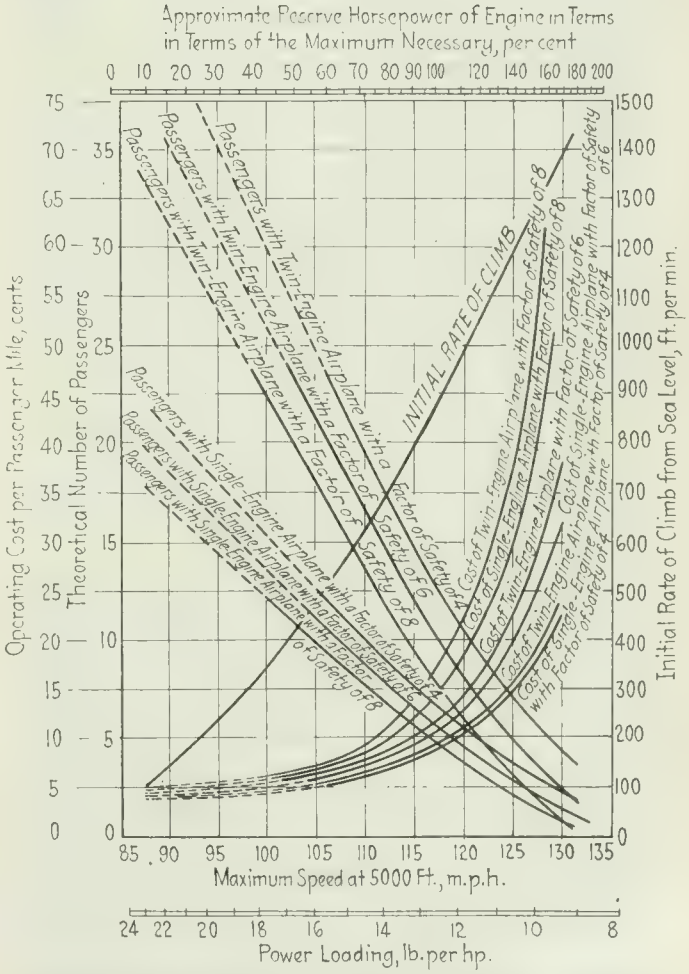

Approximate Reserve Horsepower of Engine in Terms of the Maximum Necessary, per cent
0 10 20 30 40 50 60 70 80 90 100 120 140 160 180 200
Operating Cost per Passenger Mile, cents
Theoretical Number of Passengers
Initial Rate of Climb from Sea Level, ft. per min.
Passengers with Twin-Engine Airplane with a Factor of Safety of 8
Passengers with Twin-Engine Airplane with a Factor of Safety of 6
Passengers with Single-Engine Airplane with a Factor of Safety of 8
Passengers with Single-Engine Airplane with a Factor of Safety of 6
INITIAL RATE OF CLIMB
Factor of Safety of 8
Factor of Safety of 6
Cost of Twin-Engine Airplane with Factor of Safety of 8
Cost of Single-Engine Airplane with Factor of Safety of 8
Cost of Twin-Engine Airplane with Factor of Safety of 6
Cost of Single-Engine Airplane with Factor of Safety of 6
85 90 95 100 105 110 115 120 125 130 135
Maximum Speed at 5000 Ft., m.p.h.
24 22 20 18 16 14 12 10 8
Power Loading, lb. per hp.

FIG. 1—CHART SHOWING THE VARIATION OF THE COST OF OPERATION, THE RATE OF CLIMB AND THE NUMBER OF PASSENGERS WITH THE SPEED AND THE RESERVE HORSEPOWER

These Curves Are for a Series of Single and Twin Liberty Engined Passenger Airplanes of a Constant Minimum Speed of 57 M.P.H. and a 4-Hr. Duration of Flight. The Dotted Portions of the Curves Indicate the Capacity above the Practical Limit. The Weight of the Passengers, Including Baggage, Is Assumed as 190 Lbs.

planes,[1] I considered in some detail the effect of designed performance upon the cost of operation of airplanes. Fig. 1 is taken from this paper and shows the relation between the operating cost and the speed for a series of airplanes. It is wholly practicable to increase the high speed of the machine to 105 or even 110 m.p.h. at a 5000-ft. altitude before the operating cost begins to increase seriously. This enables us to fly normally at 90 to 100 m.p.h. at this altitude. Considering Professor Warner's figure of 85 m.p.h., this possibly would fall to 80 m.p.h. at the operating altitude of about 5000 ft. Fast railroad trains make about 45 m.p.h.; thus, by the time we allow for the trip between the city and the landing-field at each end and for the intermediate stops, the margin of saving becomes rather close. We must sell our transportation upon the basis of speed and at a higher rate.

I agree fully with the remarks regarding the question of maintenance, but would also lay stress on the practicability of utilizing existing types. Metal construction, fabric substitutes and the like are still very much in the experimental stage, and we cannot expect commercial aviation to carry the cost of developing these until it first gets on its feet. In the meantime, it seems probable that they will be developed anyhow for military purposes. As it stands now, we are getting sufficiently good performance out of existing types of *commercial* airplanes to make use of these conventional constructions practicable. Airplanes are probably more reliable and sturdy than is assumed generally. The wings of our much criticized fabric-covered airplanes can be counted upon to give fully 500 hr. of service before they need to be recovered, and this length of service is being increased. We can rely upon getting a life of 800 hr. out of a good engine if we regrind the cylinders, and possibly the crankshaft, during this time. The Air Mail Service is getting a 400-hr. average life, while Aeromarine Airways, Inc., is getting about an 800-hr. life out of Liberty engines *without regrinding*. It seems to be all a matter of how we treat the engines. Operation in this country has indicated that the engine will give excellent service if overhauled on an average of once for every 100 hr. of flying. Of course, engine depreciation remains a very large item in operating cost, and every effort should be made to reduce it, but it is getting down to being within reason. Only recently, aside from the cost of getting business, it was the largest item in our costs, as new engines of commercial sizes range around $16 to $20 per hp.

Regarding airplane size, there is a certain intermediate size that is now the most economical. With the further refinements possible in the larger craft, this size will move upward, but it is obvious that we cannot perpetually evade the "square-cube" law as we might a city ordinance. We will eventually reach the size where no further refinement is possible, whereupon our "economical size" will have become permanent. Where this will bring us, we cannot tell today. Neither need we care to any extent. Our present problem is that of filling the existing sizes sufficiently to justify their operation on a close headway. In this matter of size, however, I feel that the additional safety obtainable through the provision of two pilots would justify some departure from the present economical size.

The suggestion of using two different sizes of airplane is interesting. It seems to me, however, that it is not important so long as we are operating relatively small sizes of craft. As the size of airplanes increases in the future, this probably will become important.

I agree most heartily with Professor Warner's comments on the matter of silencing engines, and feel that this subject is not getting the consideration that it deserves. I have always advocated the silencing of engines of commercial airplanes. It is true, as mentioned, that we still have other noises, but why not get rid of as much of the noise as we can? Any person who has made only one or two flights will give the "terrifying racket" of the engine as his clearest impression. This noise actually has a terrifying effect upon the layman, and is worth reducing if only for its psychological effect on the passengers.

[1] See *Mechanical Engineering*, December, 1922, p. 821.

DESIGNING MOTOR CARS

A MOTOR car is not the conception of one brain, or of the immediate staff of the builder, even excluding the units purchased complete, such as magnetos, tires or ball bearings. The accumulated wisdom of engineers, chemists and physicists innumerable is rightly accepted and used by the designer. The very fact, however, of the profusion of materials and methods that may be used makes the selection of the most suitable a task that needs a training of no mean order. Even assuming that the more complex chemical and physical experiments are left to specialists, and that orthodox materials and fuels are used, purely mechanical problems such as springing, balancing or cooling call for a vast amount of work. This labor, if it cannot be dignified by the name of research, involves much patient exploration.

Some leading companies early realized this, and provided the necessary staff and apparatus to assure that the education of their designers would be progressive and continuous. A few standardized their design so that designers were unnecessary. Most firms, however, produce a new or modified design about every 3 years, so that work must be carried on in order that the new model may be an improvement on the old, either in lower cost or in increased value to the user. At some period a decision has to be made on fundamental design questions, such as high-speed or low-speed engines sleeve or poppet valves, center or side change; and the functioning of the "designing machine" at these crucial moments may have either a very favorable or a decidedly adverse effect on a firm's reputation.

There are many ways of producing a motor car, more than one way of producing a cheap motor car, but few ways of producing a good motor car cheaply. Even in the hurly-burly of keeping abreast of contemporary design, a large staff is necessary to carry out drawing-office and experimental work, yet this shows no immediate improvement in the profit and loss account. If anything new be contemplated, such as magnetic brakes, supercharged engines or a novel transmission, very many experimental sprats must be thrown to catch the production mackerel.

Modern mechanism is too complex to be evolved from the inner consciousness of any man, however brilliant. Neither does a new constructional method often arise by some flash of genius. Such things are built up step by step, with many false turnings and fresh starting points.—*Automobile Engineer* (London).

Simplification Conference Committee

United Interests of Automotive Industry Pledged to Foster Automotive Engineering Standards at Session Held at United States Department of Commerce

"EVERY great structure requires the process of time. The new and the difficult are always being worked over in the universal consent of common-sense." The Society has been working on automotive engineering standardization problems for over 12 years. The fundamental merit behind the idea of "standards" is generally accepted. No standard can ever be adequate for 100 per cent of the applications into which it might enter but obviously the benefits that accrue from general or near-universal use are not to be sacrificed. It is about axiomatic that so long as the product of one manufacturer meets that of another the details of the juncture should be standardized. Every one concerned in the production or use of apparatus is benefited by its rational standardization.

To formulate and establish successful standards, it is necessary to have cooperative action and mutual concession among all interests. Some standards are, of course, of such public interest that laws requiring their adoption are passed. The process of automotive standardization has been in effect in this Country for 20 years. The Society is committed to the policy of evolution as opposed to any ideal classification or scheme. To standardize some things in all industries is possible. To standardize all things in all is impossible.

It is too easy to think and say that the customer pays and that therefore standardization does not matter to the manufacturer. Standardization is a method of avoiding reprehensible waste. An object of standardization is to express what is good practice, by the definition of terms and the specification of properties and dimensions. The slogan is, do the best possible, but do something; and make changes where necessary. Unnecessary sizes should not be involved in manufacturing. Products should be improved and reduced in cost.

It is not an object or an effect of standardization to make all apparatus out of the same mold, but to bring together the experience of the best qualified men for the purpose of securing better materials, broader outlook in the work as a whole and satisfactory service. It economizes building operations without interfering with the engineer's ability. It increases competition. It makes possible uniformity in material and of important dimensions involving interchangeability, the user benefiting in that he can secure replacements quickly and at less cost, service being maintained with less investment. There is no advantage to any single company in not participating in the establishment and practice of rational standardization. Neither is there any advantage in the way of design. In worldwide trade, as well as in domestic trade, it is obvious that the maintenance of standardization that will make possible the interchangeability of many materials, parts and accessories, is economically requisite. There is no doubt that S. A. E. Standards have lowered greatly the cost of production of automobiles and enabled manufacturers to market their product at lower figures than would have otherwise been possible. The current models show more resourcefulness in design than ever before, while standardization of their component parts has increased.

The need for extending the work of standardization in scope and intensity is becoming realized more in an effective sense in that the whole-hearted attention and cooperation of leading executives in the industry are being had. The full benefits of standardization cannot be secured in the face of executive opposition or their listless acquiescence. The big stake involved necessitates that all the interests shall pull together. The satisfactory solution of the service problem can be hastened greatly by a greater observance of standardization. As has been said, common-sense is merely a substratum of experiences out of which judgments flow. Each and every interest must "cog-in" with all other interests that are cogs in the operations of the whole industry and body of users. Standardization accomplishments to date represent the heart and brain of automotive engineers as a whole.

Commerce Department Meeting

A meeting held in the city of Washington last month under the auspices of the Department of Commerce was attended by official representatives of practically all of the national automotive associations and representatives of some effective local organizations such as the automotive electric service associations located in various cities. After discussion throughout the day, a resolution was passed to the effect that a committee, to be styled the Simplification Conference Committee, of not less than 11, should be appointed to assist the Society of Automotive Engineers in "selling" the standards now in existence, and in solving problems of simplification to be defined. M. L. Heminway, general manager of the Motor & Accessory Manufacturers' Association, was named chairman, and C. E. Quinn, of the Automobile Body Builders' Association, was designated as secretary of the committee. The following organizations, in addition to the Society and those named above, have been asked to nominate representatives on the Committee:

National Automobile Chamber of Commerce
Motor Truck Industries
National Automobile Dealers' Association
Automotive Equipment Association
Automotive Electric Association
American Gear Manufacturers' Association
American Automobile Association
National Hardware Association
Rubber Association of America
Aeronautical Chamber of Commerce
Motorcycle and Allied Trades Association.

In addition to the organizations named above and several representatives of the trade press, the following were represented at the meeting in Washington:

United States Chamber of Commerce
Bureau of Foreign and Domestic Commerce
Bureau of Standards
American Railway Express Co.
Motor Truck Association
Motor Transport Corps of the Army
American Society of Agricultural Engineers
Automotive Metal Wheel Manufacturers' Association

Chairman Heminway, in communicating with the organizations asked to designate representatives, stated that it is the purpose of the committee to supplement and assist existing standards committees for the benefit broadly of the industry and the users of automotive vehicles. It is expected, of course, that the committee will receive thoroughgoing support from the various organizations inasmuch as it is clear that the education of all in the possibilities and necessities of wide reduction to practice of sound standards should result in much improved conditions in the servicing and maintenance of automobiles. It is essential that the public, as well as the dealers, have a clearer understanding of the need and functions of standards.

As has been announced in The Journal, the following subjects were selected some time ago for promulgation under the methods of the Department of Commerce, by the Simplified Practice Committees of the Society and the Na-

tional Automobile Chamber of Commerce, of which J. G. Vincent and F. E. Moskovics are chairmen respectively:

Roller Bearings
Storage-Batteries
Pneumatic Tires
Spark-Plugs

William A. Durgin, chief of the division of simplified practice of the Department of Commerce, in addressing those attending the Washington meeting, showed by submission of data collected by the Department that the lack of standardization is the principal cause of waste in industry. He stated emphatically that simplification would reduce users' first, accessory and maintenance costs, the decrease in the number of sizes enhancing quality and also the profit to all concerned. He said that there is nothing more constructive in the automotive industry than the S. A. E. HANDBOOK. He urged that this be given publicity and in general that the best thought of the industry be supported. The Department's method of dissemination of information in this connection is the issuance of pamphlets setting forth practices approved by industry, the Bureau of Simplified Practice advising that the standards in question be made universal. He made it plain that the Department of Commerce can do nothing in this respect unless the automotive industry makes specific recommendations. He explained that R. M. Hudson, of his Division, would assist the work in every way possible so far as the Department of Commerce is concerned.

C. C. Hanch, vice-president of the National Automobile Chamber of Commerce, asserted that further standardization work should be done in the tire and other automotive fields. He expressed the opinion that the human side of the whole problem should be studied and the men who pay the bills and sell in the field have a plan of coordination and cooperation. At present the service manager does the best he can when the factory engineering and production departments with which he is connected do not work as effectively together as they should. The large dealers are a very potent influence in the situation. He commended very highly the standards work of the Society, pointing out that it had carried on practically all of the work involved; not being supported sufficiently and perhaps being to blame for this itself. He advised concentrating on the things that affect directly the use of cars, stopping short of those matters that have to do with individuality and style and the necessary catering to personal tastes.

A. J Grimm, chairman of the standards committee of the Automotive Equipment Association, explained current and proposed methods of that association in propagating the standardization idea in its connections with both car builders and jobbers, a large part of this work being devoted to the explanation and recommendation of S. A. E. Standards.

A. D. T. Libby, president of the Automotive Electric Association, argued that in the solution of the big standardization problems involved it will be necessary to enlist adequate support from leading executives of the motor-car industry, upon whom rests an obligation to ascertain why automotive equipment standards, for example, are not used to a greater extent. The number of parts now needed for servicing is tremendous and without the direct assistance of the executives the fight will be a long uphill one. He explained the effort that is being made by the Automotive Electric Association to establish standard capacity-ratings of electrical generators.

E. E. LaSchum, in charge of motor-truck transport for the American Railway Express Co., said that standardization had resulted in great benefit in such work as his, there being considerably more interchangeability of parts than is generally understood. He said that the cost of the stock of maintenance parts of his company is less than $42 per truck. He expressed the opinion that for reliability of performance the motor truck is unexcelled.

Col. Edgar S. Stayer, U. S. A., stated that if this Country should engage in war under present conditions it would be necessary to stock 250,000 different articles for replacements in motor vehicles, not including accessories and tires. The Government is still confronted with an unjustifiable diversity of repair parts. The present Army maintenance stock costs $60 per truck. Standardization is approved by the War Department, which desires especially consideration of emergency conditions. The more exactly alike the various elements are, the better the conditions will be. Commercial trucks are good and will do what they were designed to do, but must be handled properly.

Clyde Jennings, editor of *Motor Age*, said that at present owners do not know where to purchase replacement parts for their cars, and in addition that the flat-rate system of maintenance is of the greatest assistance in reaching a proper standardization basis. He feels that in the end the maintenance man will control the situation. In most towns at present not more than one or two makes of storage-battery are available for purchase. There are a great many specially made batteries for cars and the size and installation of the batteries are not considered adequately in car design. The inside dimensions of batteries are well standardized but not the outside dimensions. In conclusion, Mr. Jennings urged strongly that the people who control the whole situation be properly educated.

James Dalton, editor of *Automotive Industries*, said that general preaching is not effective in standardization. Standardization is "approved" in general, but in factory purchases immaterial sixteenths are insisted upon. To an undue extent standardization is fine theoretically "for the other fellow." The manufacturers must be sold on the application of standards. Talk will do nothing. His view was that one or two specific things should be concentrated upon for accomplishment within the year. The trade press wants some such definite aim outlined.

D. C. Fenner advised holding joint meetings of executives and engineers to discuss the whole matter.

R. W. Trullinger, of the American Society of Agricultural Engineers, stated that there is inadequate encouragement and development of research work in the tractor industry; that much engineering knowledge is to be acquired and that the engineers do not receive proper support.

Norman G. Shidle, managing editor of *Automotive Industries*, said that a sales organization is needed for the standards work and proposed that the meeting select a committee to assist the Society in coordinating the standards work as a whole, chiefly in the direction of further reduction to practice.

WEAR OF STEELS

SEVERAL tests have been conducted by the Bureau of Standards to determine the resistance to wear of hardened and tempered chromium steels. It was noticed that while the so-called standard hardened specimen, which was run on the upper shaft of the testing apparatus, invariably had a polished surface at the conclusion of every test, the bottom specimen, especially when tempered, presented a dull appearance that was presumed to be caused by abraded particles sticking to the specimen. It seemed, therefore, that specimens with this dull mottled appearance would show a loss of weight less than the actual loss. To prove this several tests were made of Ketos steel running the standard hardened specimen on the lower shaft and the tempered specimens on the upper shaft. The curve of the rate of wear plotted against the tempering temperature was similar to the previous curve but showed a greater rate of wear.

The tempered specimens under the last-named conditions were free from abraded material at the end of the tests. Efforts will be made to prevent the adherence of the abraded metal particles to the specimen.

Laws Governing Gaseous Detonation

By Thomas Midgley, Jr.[1] and Robert Janeway[2]

Annual Meeting Paper *Illustrated with* Photographs and Charts

THE authors present in this paper an explanation of gaseous detonation based upon what are considered incontrovertible laws, and show by the functioning of these well understood natural laws that gaseous detonation is a phenomenon that does not require any hypothetical assumptions to account for its existence.

The physical conditions that must exist within an enclosed container when it is filled with an explosive mixture of gases and these gases are ignited are stated and analyzed mathematically, and an application of this analysis is made to the internal-combustion engine. The apparatus and the procedure are described, inclusive of photographs and charts, and it is shown how the formulas can be applied (*a*), for constant throttle and varying the temperature of the entering charge and (*b*), for constant temperature and varying the throttle opening and the compression-ratio. The results are illustrated and discussed in some detail.

Appendix 1 refers to the basic equations in the paper and has as its object the combination of these equations

$$P_1 - P_2 = W^2/g\ (V_2 - V_1)$$
$$W = KD_1^n T_1^m$$

into a single fundamental expression containing P_1 and P_2 as the only variables.

Appendix 2 is a mathematical determination of the critical pressure of detonation.

THE phenomenon of gaseous detonation has been recognized for many years. As early as 1888 it had been studied extensively by Bertholet and Le Chatelier of France and also by Harold B. Dixon of England. Since that time many other investigators have studied this phenomenon, as well as studying the normal combustion of gases as it occurs under varying conditions. Unfortunately, up to the present, investigators of gaseous detonation have been so busy collecting data that no one of them has taken the time to investigate the phenomenon from a theoretical standpoint, or to explain it upon the basis of sound fundamental laws. Gaseous detonation has, therefore, remained comparatively unexplained. It is our belief that, if a phenomenon can be explained fully by known and proved laws, there is no justification for any explanation based upon unsubstantiated assumptions. Therefore, we desire to present in this paper an explanation of gaseous detonation based upon what are considered to be incontrovertible laws, and to show by the functioning of these well understood natural laws that gaseous detonation is a phenomenon that does not require any hypothetical assumption to account for its existence.

First, let us determine what physical conditions must exist within an enclosed container when it is filled with an explosive mixture of gases and these gases are ignited. Fig. 1 represents what would be a series of instantaneous photographs of flame-travel within a cylinder, were it possible to make such photographs. These diagrams are not assumptions, but are based upon actual observations

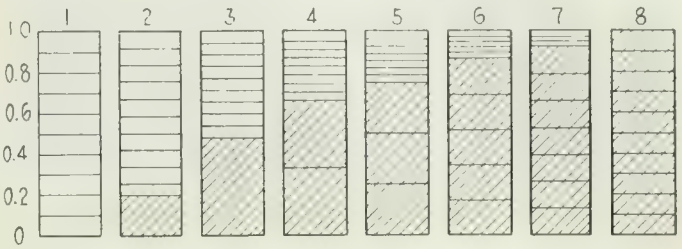


Fig. 1—Diagram Illustrating Flame Travel in a Cylinder

by Woodbury, Lewis and Canby, in their paper on The Nature of Flame Movement in a Closed Cylinder,[3] and a mathematical analysis thereof made by Thomas Midgley, Jr., on Molecular Movements During Combustion in Closed Systems.[4] Diagram No. 1, in Fig. 1, represents a bomb filled with a combustible gas mixture with division lines between each one-tenth portion of this mixture. No. 2 represents the partial combustion of the first one-tenth. No. 3 represents the total combustion of the first one-tenth and Nos. 4, 5, 6, 7 and 8, represent successive stages of the process. It will be observed that by the time the first one-tenth of this gas has burned, it has expanded as indicated in No. 3 and thereby compressed ahead of it the remaining nine-tenths of unburned mixture. Also, it will be observed in No. 4 that, as the second one-tenth burns, it is not only compressing the gas ahead of it but likewise the gases to its rear. If the positions of the various particles as they move along the bomb are plotted against time, we will obtain a diagram such as that shown in Fig. 2. This chart is called a displacement diagram because it shows the displacement of the particles from their initial positions within the bomb. If now we follow

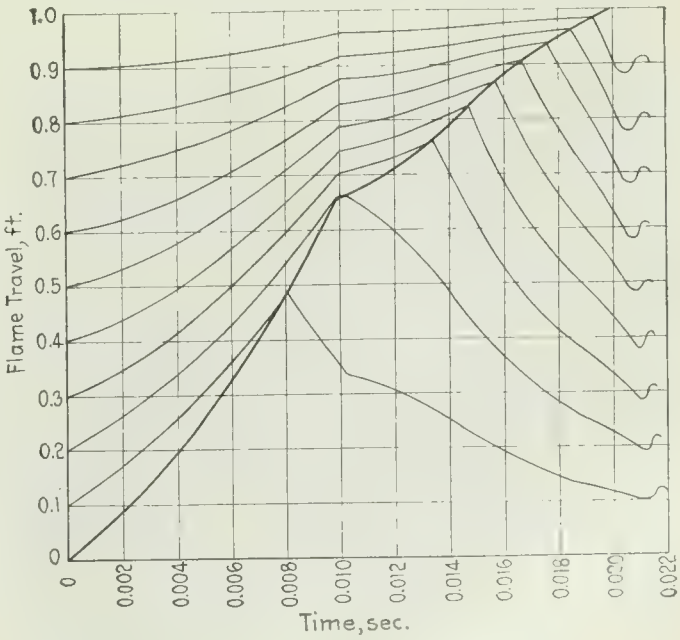


Fig. 2—Displacement Diagram of the Particles During Total Combustion

[1] M.S.A.E.—Chief engineer, fuel section, General Motors Research Corporation, Dayton, Ohio.

[2] Mathematician, fuel section, General Motors Research Corporation, Dayton, Ohio.

[3] See The Journal, March, 1921, p. 209.

[4] See The Journal, May, 1922, p. 357.

the behavior of a single particle such as the one that is two-tenths of the way up the bomb, before ignition, it will be observed that just before the flame-front overtakes this particle it has an upward velocity with respect to the bomb and that, just after the flame-front has passed through it, the particle has a rearward velocity with respect to the bomb. Since this particle has mass and has had its velocity changed, one of the most fundamental laws of physics dictates that there must have been a force acting in the direction of this change of velocity. Now the only force that can be operating in a space containing gases alone is a pressure difference within these gases themselves. Therefore, it is obvious that a slightly greater pressure must exist ahead of the flame-front than behind it. From the fundamental law that force equals mass times acceleration, we can derive a mathematical expression for this difference of pressure. It is:

$$P_1 - P_2 = W \cdot g \cdot (V_2 - V_1) \qquad (1)$$

where

$g = 32.2$
P_1 = the pressure ahead of the flame-front, in pounds per square foot
P_2 = the pressure to the rear of the flame-front, in pounds per square foot
V_1 = the specific volume of gases, in cubic feet per pound, corresponding to P_1
V_2 = the specific volume of gases, in cubic feet per pound, corresponding to P_2
W = the weight of the gas, in pounds, that enters the flame-front per second

In the above equation, it is obvious that the magnitude of the pressure-difference is dependent upon W, the weight of gas entering the flame-front per unit of time. Therefore, we can continue our analysis profitably by investigating the nature and the factors that control W.

In physical chemistry, the weight of gas entering the flame-front per unit of time is known as the reaction-velocity. Physical chemists have done a great amount of work in establishing laws with regard to reaction-velocities. For this case, the following equation has been proposed:[5]

$$W = K \times D^n T^m \qquad (2)$$

where

D = the density, or concentration
K = a constant to be determined experimentally.
n = an exponent to be determined experimentally
m = an exponent to be determined experimentally
T = the absolute temperature

As an alternative to this treatment of W, we can substitute $W = KD^nC^T$; where C is another constant to be determined experimentally. However, this becomes decidedly ponderous in the further development, and does not appear to be any more accurate than the treatment selected. Both expressions appear to be close approximations, neither being absolute. For example, n should be a whole number and probably would be were the treatment of T perfect; otherwise, n will vary so as to compensate for the error in the treatment of T. The treatment we have selected gives n a value of 0.9 and, using the alternate method, we obtain for n a value of 1.1. The mean of these two values gives n equal to unity, which is probably correct. Since no accepted treatment of T gives n this value, the treatment that is most easily handled mathematically has been selected.

To return to the discussion proper, it will be observed that the equation $W = KD^nT^m$ applies to conditions obtaining in the immediate front of the flame-front, and not to the conditions to the rear of the flame-front. In other words, $D = 1/V_1$ and T is the temperature corresponding thereto. Thus it is obvious that the pressure-difference depends mainly upon W; and that W, in turn, is a function of the pressure ahead of the flame-front.

To make clear the above relationships let us consider an actual case substituting numerical values. Our equations are

$$W/g = LP_1^Q \qquad (3)$$

where

$Q = 3$ (See Appendix 2)
$W = BP_1^3$
$B = 0.061$

$$P_1 - P_2 = (W \cdot g) \cdot (C \cdot P_2) \qquad (4)$$

where

$C = 835$ (See Appendix 1)

When $P_1 = 252$ lb. per sq. in. absolute, by substitution in (3) we have

$$W = 0.061 \times (252)^{1.5}$$
$$= 241 \text{ lb. per sec.}$$

Substituting in (4) we have

$$144\,(252 - P_2) = (241/32.2) \times (835/P_2)$$

solving

$P_2 = 200$ lb. per sq. in. absolute
$P_1 - P_2 = 52$ lb. per sq. in. absolute

[5] See Physical Chemistry for Colleges, by Millard, pp. 303 and 310; see also Chemical Statics and Dynamics, by Mellor, pp. 383 to 393; see also Theoretical Chemistry, by Nernst, (10th German edition) pp. 750 to 754

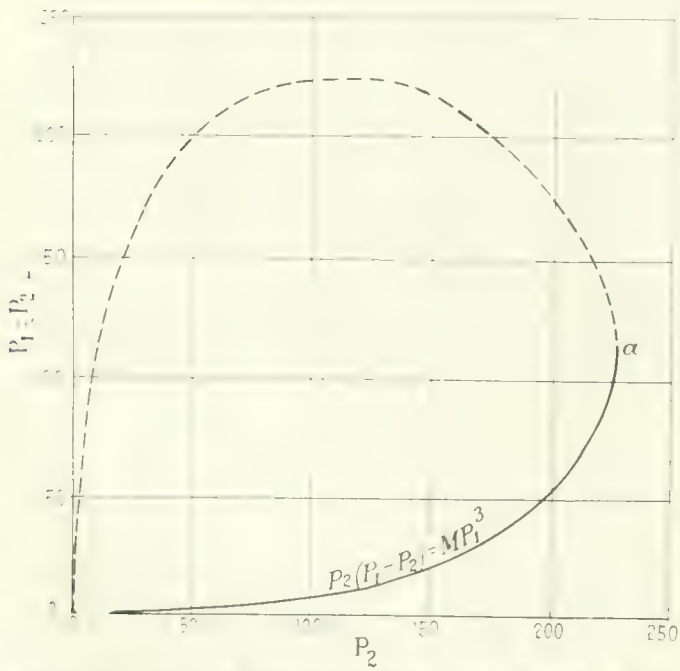


Fig. 3—Chart of the Relation between the Pressure in the Rear of the Flame-Front and the Difference between This Pressure and That Ahead of the Flame-Front during the Combustion Process

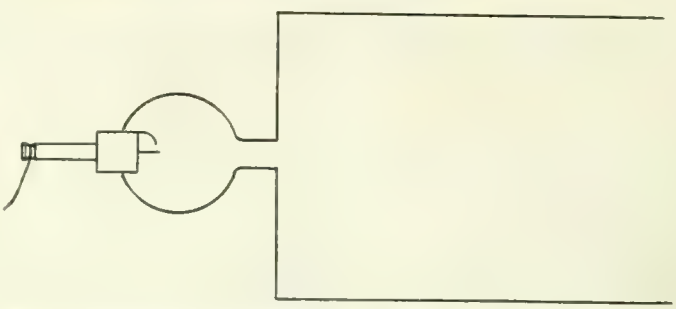


Fig. 4—Apparatus Employed to Verify the Mathematical Analysis of Pressure Relations in Combustion

This value is an actual point used in plotting the curve of Fig. 3.

It will be expedient, therefore, to combine these two equations into one expression. Appendix 1 gives the mathematics involved in deriving and simplifying this expression.

In its final form it becomes—

$$P_1 - P_2 = (MP_1Q - P_2) \qquad (5)$$

If now some definite values are assigned to M and Q and this expression is plotted, a curve as given in Fig. 3 is obtained.

It is quite obvious that, in the actual phenomenon of combustion, P_2 cannot reduce from the point a but must increase as combustion continues. What actually takes place at this point is a sudden enormous increase in the reaction velocity and hence in the pressure differential. The extent of this increase is governed by some limiting factor or factors other than those already taken into account and irrelevant to the purposes of this paper. Probably the major factor involved is the limiting of the flame travel to the velocity of sound which the rate of transmission of molecular activity cannot exceed.

Before continuing the analysis and applying it to the internal-combustion engine it will be well to consider briefly the result of open-tube experiments in the light of the above analysis. H. B. Dixon, in his paper on the Movements of the Flame in the Explosion of Gases,[6] describes the phenomenon of combustion in an open tube as follows:

> When a mixture of carbon disulfide and nitric oxide was fired near the closed end of the tube, the movement of the flame uniformly accelerated until the detonation wave was set up.
>
> In explosions starting at the open end of the tube, the development of the detonation wave is not progressive but always instantaneous. The detonation wave is characterized not only by its great velocity of movement, but by its intense luminosity and the very high pressures instantaneously set up in it.
>
> Our photographs have shown that the wave of detonation has certain characteristics by which it may be readily recognized: (*a*) it starts suddenly, and (*b*) it travels with constant velocity.

With Dixon's description in mind, note how closely it parallels the mathematical analysis. In Fig. 3, the flame-front has been progressing with a slightly accelerating velocity up to the point a, when its velocity suddenly jumps to a very high value at which it remains constant.

A further experiment verifying the mathematical analysis is described as follows: Fig. 4 represents a short open tube filled with a combustible mixture of gases adapted to be ignited from the small chamber at the left that contains a spark-plug. Upon igniting the charge in this small chamber, a detonation wave will be set up and issue into the large chamber; whereupon the entire volume of gas in the latter will detonate, although its pressure is far below the critical value, a, of P_2. But for any value of P_2 as stated above, P_1 may be infinite. Consequently, if this bulk of gases be ignited by a detonation wave, detonation of the whole will result.

Application to the Internal-Combustion Engine

The application of the foregoing to the internal-combustion engine is not an easy task. In studying gaseous detonation in bombs and explosion tubes, we have the gas in a quiescent state and in regularly shaped chambers with an organized flame-front proceeding through it. We meet, in the internal-combustion engine, turbulence and irregularly shaped combustion-chambers with varying spark-plug locations still further complicating the situation. To take all these factors into account is an almost impossible mathematical task. However, by assuming that in a specific engine these factors affect the constant of the reaction-velocity, the procedure is simplified greatly.

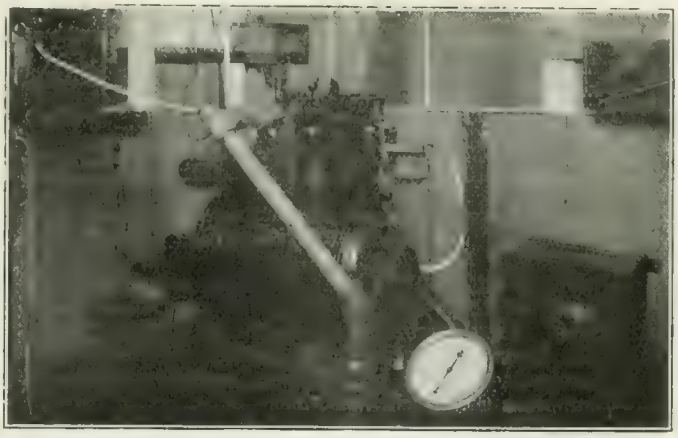


Fig. 5—The Single-Cylinder Delco-Light Plant Used in Making the Experiments

Before attempting to apply the laws governing gaseous detonation specifically to the internal-combustion engine, it may be well to give the reasons for our certainty that gaseous detonation within the engine cylinder is the phenomenon that causes engines to knock.

(1) A high-pressure high-velocity detonation-wave striking the cylinder-head *should* distort it and thereby produce the metallic noise that is called a knock

(2) The luminosity that is observable during gaseous detonation in an explosion tube is also present in the flame within the cylinder when the engine knocks

(3) Anti-knock materials, such as diethyl selenide and tetraethyl lead, could scarcely affect the auto-ignition temperature of a fuel when used in the very small quantities that are necessary to suppress knocking. Apparently, the only way to explain

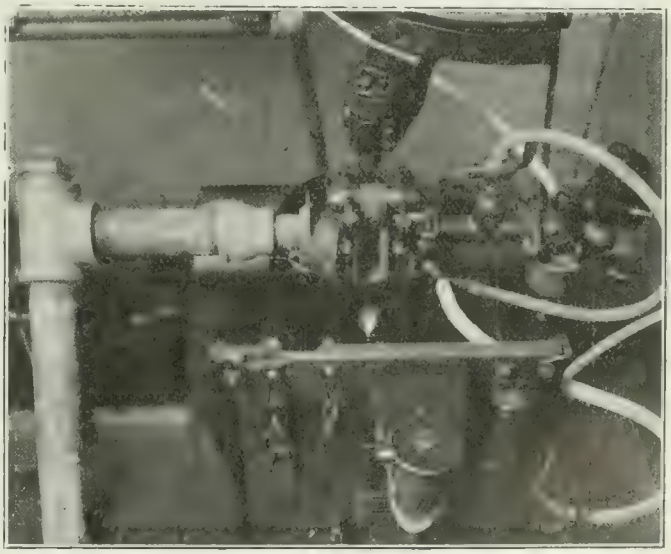


Fig. 6—Looking Down on a Portion of the Engine Used in the Experiments

[6] See *Transactions of the Philosophical Society*, vol. 200, p. 315.

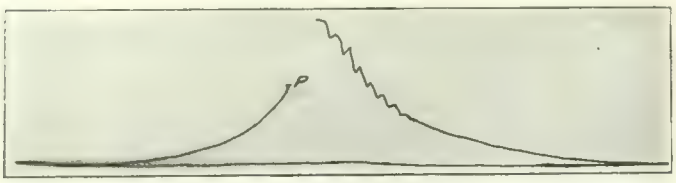


FIG. 7 A SAMPLE INDICATOR-CARD OBTAINED IN MAKING THE EXPERIMENTS

their effect is on the basis that they affect the constant of the reaction velocity of gaseous detonation. Furthermore, these materials will suppress the detonation occurring in explosion tubes to the same degree and in the same manner that they suppress the knock in engines

The automotive engineer is interested primarily in the factors that affect the point at which detonation will take place, rather than in the nature of detonation. Therefore, we will continue our analysis with the object of indicating what factors are important and how their variation affects the critical pressure at which detonation will take place.

If we differentiate P_2 of equation (5) with respect to P_1 and equate to zero, as shown in Appendix 2, we obtain the following expression for the critical pressure of P_2, or the point a in Fig. 3.

$$P_2 = Q^{\frac{2}{Q-1}} [(Q-1)^{\frac{Q}{Q-1}}] / MQ^Q \qquad (6)$$

where

C_p = the specific heat at constant pressure of the charge, and can be assumed from existing laboratory data

C_v = the specific heat at constant volume

D_0 = the density, obtained from the running engine

h = the number of British thermal units that can be liberated by the combustion of 1 lb. of cylinder charge, taking into account the effect of exhaust-gas dilution; and it can be calculated when the mixture-ratio, the manifold depression, the compression-ratio and the heating value of the fuel are known

$M = [(K^2 D_0^{2n} T_0^{2m}) / (g \times P_0^Q)] [hR/C_p)]$

m = a quantity to be determined experimentally

n = a quantity to be determined experimentally

P_0 = the pressure at the closing of the intake valve, obtained from the running engine

P_2 = the critical pressure of detonation, which can be obtained from an indicator card taken on the engine

$Q = 2[n + m(y-1)]/y$

$R = 778 (C_p - C_v)$

T_0 = the absolute temperature, obtained from the running engine

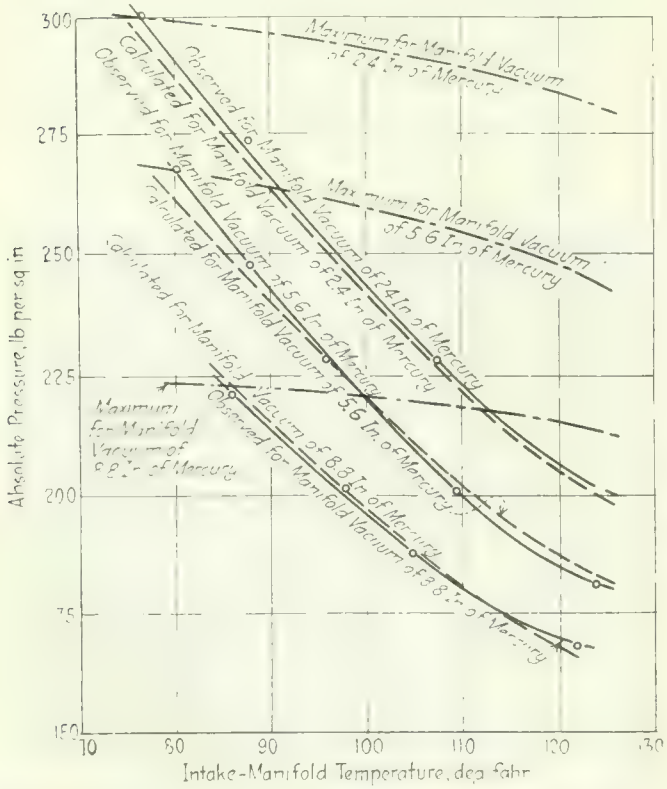

Maximum for Manifold Vacuum of 2.4 In. of Mercury
Observed for Manifold Vacuum of 2.4 In. of Mercury
Calculated for Manifold Vacuum of 2.4 In. of Mercury
Maximum for Manifold Vacuum of 5.6 In. of Mercury
Observed for Manifold Vacuum of 5.6 In. of Mercury
Calculated for Manifold Vacuum of 5.6 In. of Mercury
Maximum for Manifold Vacuum of 8.8 In. of Mercury
Observed for Manifold Vacuum of 8.8 In. of Mercury
Calculated for Manifold Vacuum of 8.8 In. of Mercury
Absolute Pressure, lb. per sq. in.
Intake-Manifold Temperature, deg. Fahr.
300
275
250
225
200
175
150
10
50
90
100
110
120
130

FIG. 8—CURVES SHOWING THE EFFECT OF THE MANIFOLD TEMPERATURE ON THE CRITICAL PRESSURE OF DETONATION

By taking a sufficient number of readings from the engine and substituting in equation (6), the values of Q, n and m can be determined.

APPARATUS AND PROCEDURE

The experimental apparatus consisted of a single-cylinder 2 1/2 x 5-in. Delco-Light plant with the generator loaded on rheostats and equipped with a Midgley indicator, as shown in Figs. 5 and 6. The compression-ratio was 4.1 to 1, and this sufficed to produce violent detonation when using kerosene as fuel.

The indicator was used to determine the point of detonation, which was defined by the sudden fading of the light on the pressure-time card because of the rapid acceleration of the indicator mirror. That this point should be considered as P_2 is debatable. It is our opinion that, during engine operation, the combustion is without a well organized flame-front, due to turbulence and the like, and that P_1 exists only over the limited region in the immediate front of the flame. On the indicator-card, this will appear as a part of the rise due to detonation. Fig. 7 shows a sample card with the point of detonation at P.

As a means of measuring the manifold depression directly with a mercury manometer, a small valve, actuated by the inlet-valve rocker-arm, was interposed between the manifold and the manometer. The manometer valve was synchronized with the inlet-valve so as to open only during the time that the inlet valve was open, thus preventing any error in reading due to pressure variation in the manifold. This reading was checked with an intake-manifold indicator and found to be satisfactory. It does not take into account the drop across the intake-valve and, consequently, is in slight error. The manifold temperature was measured with an ordinary thermometer. Although such a means of measurement admittedly does not give accurate results, it is satisfactory for comparative purposes.

TABLE 1—TEST DATA FOR FIG. 8

No. of Run	Manifold Temperature, Deg. Fahr.	Engine Speed, R.P.M.	Manifold Vacuum, In. of Mercury	Critical Pressure, Lb. per Sq. In., Absolute
1	77.0	Constant at 925	2.4	300
	88.0		2.4	274
	107.5		2.4	228
	124.5		2.4	201
2	80.5		5.6	268
	88.0		5.6	248
	96.0		5.6	228
	109.0		5.6	201
	124.0		5.6	181
3	86.0		8.8	221
	97.5		8.8	201
	104.5		8.8	188
	113.0		8.8	177
	122.0		8.8	168

Several runs were made at constant throttle. Beginning at about 25 deg. cent. (77 deg. fahr.), at which temperature in the manifold detonation began, indicator-cards were taken at 5-deg. cent. (9-deg. fahr.) intervals up to 50 deg. cent. (122 deg. fahr.). The speed was maintained constant throughout all runs. Several fuel-consumption determinations also were made during each run, so that the comparative mixture strength might be known. The carbureter adjustment, as well as the spark setting, remained unchanged throughout all the runs.

The data obtained by the foregoing method can now be substituted in equation (6) and the equation solved. The substitutions are omitted for the sake of brevity, but the data are given in Table 1. The values determined experimentally are $Q = 3$; $n = 0.9$; and $m = 3.22$. Thus, the equation becomes

$$P_2 = 0.148/M \qquad (7)$$

where

K = a constant depending upon the nature of the fuel, the speed, the spark setting and the engine design

$M = [(K^2 D_0^{1.8} T_0^{6.44}) / (g \times P_0^3)]\,[(hR/C_p)]$

Thus, if the combustion efficiency remains constant, the variables that alone govern the detonation point for any given engine, at a given speed and spark setting, are the initial mixture-conditions of density, temperature and pressure and mixture-ratio. It must be understood clearly that this formula defines merely the maximum pressure that must not be exceeded during combustion under any given set of conditions if detonation is to be avoided. Also, the constant K must be determined experimentally for any particular engine.

The formula can now be applied to the specific conditions that it is desired to investigate. For example, in the engine from which these data were obtained, *for constant throttle and varying entering-charge temperature.*

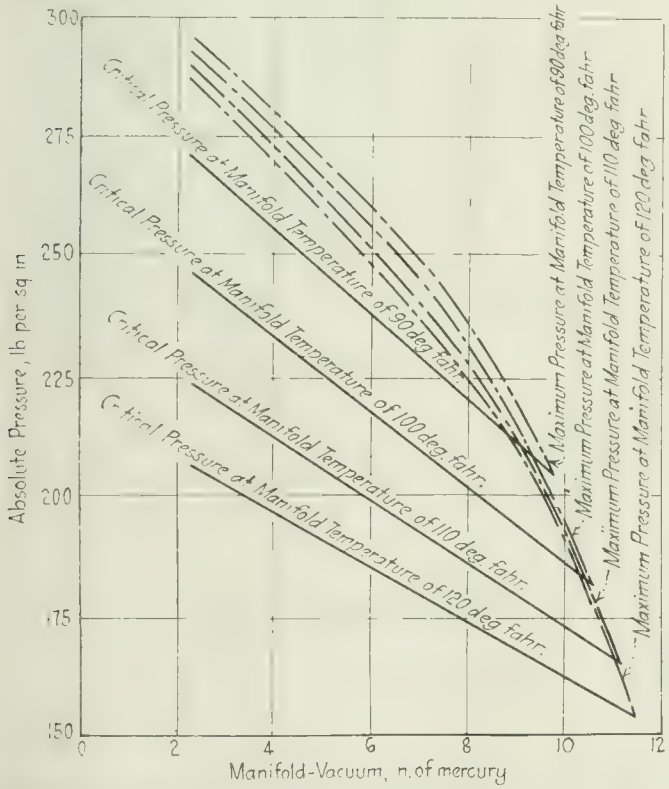

Absolute Pressure, lb per sq in
Manifold-Vacuum, in. of mercury
Critical Pressure at Manifold Temperature of 90 deg fahr.
Critical Pressure at Manifold Temperature of 100 deg. fahr.
Critical Pressure at Manifold Temperature of 110 deg fahr.
Critical Pressure at Manifold Temperature of 120 deg fahr.
Maximum Pressure at Manifold Temperature of 90 deg fahr.
Maximum Pressure at Manifold Temperature of 100 deg fahr.
Maximum Pressure at Manifold Temperature of 110 deg fahr.
Maximum Pressure at Manifold Temperature of 120 deg fahr.

FIG. 9—THE EFFECT OF THE MANIFOLD VACUUM ON THE CRITICAL PRESSURE OF DETONATION IS SHOWN BY THESE CURVES

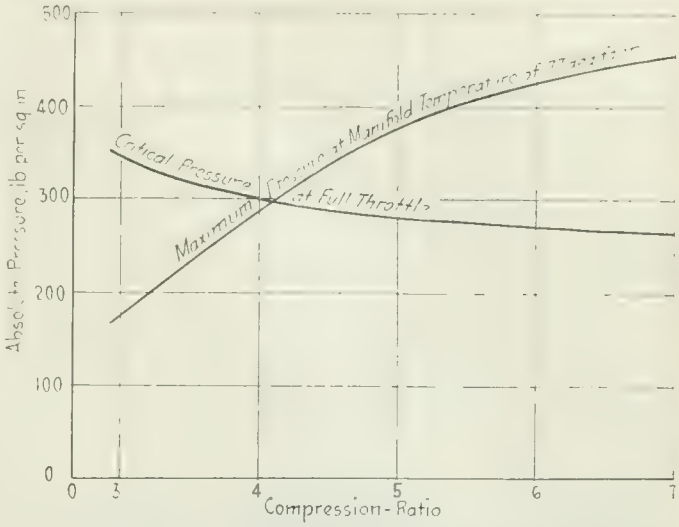

Absolute Pressure lb per sq in
Compression-Ratio
Critical Pressure
Maximum Pressure at Manifold Temperature of 77 deg fahr
at Full Throttle

FIG. 10—CURVES SHOWING THE EFFECT OF THE COMPRESSION-RATIO ON THE CRITICAL PRESSURE OF DETONATION

$$P_2 \propto 1/D_0^{1.8} T_0^{6.44}$$

Since $D_0 \propto 1/T_0$ when P_0 = a constant, we have

$$P_2 \propto 1/T_0^{4.64} \qquad (8)$$

This shows the predominating influence of temperature on the pressure at which detonation will occur.

For constant temperature and varying throttle and compression-ratio

$$P_2 \propto 1/[(D_0^{1.8} \times h)/P_0^3]$$

Since $D_0 \propto P_0$ at constant temperature and $h \propto 1 - [\{C\,l\,(P_a/P_0)\}/C\,V]$, the effect of exhaust-gas dilution, where P_a = barometric pressure

$$h \propto 1 - (P_a/rP_0)$$

When r = compression ratio

$$P_2 \propto \frac{P_0^{2.2} r}{rP_0 - P_a} \qquad (9)$$

It is evident from the foregoing two formulas that density serves merely to modify the effects of the determining factors, temperature and pressure.

It should be emphasized that the pressure at which detonation occurs is independent of the compression-ratio, except insofar as it affects the effective heating value by varying the amount of extaust-gas dilution in the cylinder charge. It appears in this connection in equation (9). The compression-ratio really influences knocking to the greatest extent by affecting the maximum pressure attained in the engine.

DISCUSSION OF RESULTS

The curves in Fig. 8 show the variation of detonation pressure with intake-manifold temperature for different throttle positions, the speed and the spark setting remaining constant. Each pair of curves is plotted from the observed data, and the corresponding calculated data, and is accompanied by a curve showing the corresponding variation of final pressure, as calculated. It is obvious that the tendency of the engine to detonate is shown by the relation of the final pressure curve to that of detonation pressure; the point of intersection marks the transition from normal to detonating combustion, the intensity of detonation increasing with temperature beyond this point. It is observed that the point of intersection occurs at slightly higher temperature as the throttle is closed. The observed and the calculated curves are prac-

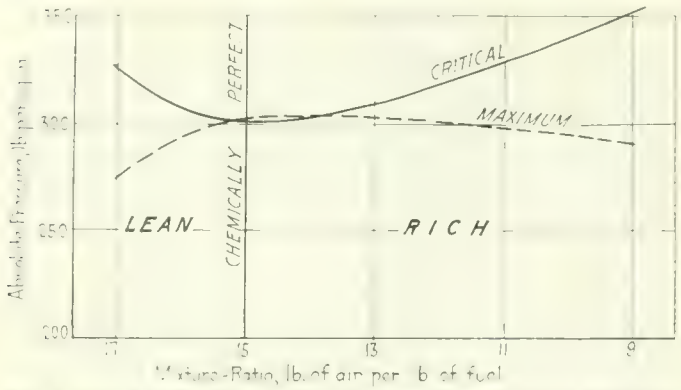


FIG. 11—HOW THE MIXTURE-RATIO AFFECTS DETONATION IS BROUGHT OUT BY THESE CURVES

tically coincidental, the maximum discrepancy being no greater than the probable experimental error.

The curves of Fig. 9, showing the variation of detonation pressure and maximum pressure with manifold depression at various constant temperatures, were plotted from the curves of Fig. 8. The final-pressure and detonation-pressure curves of Fig. 8 converge toward the point of intersection, at which point detonation disappears. As the temperature decreases, the point of intersection can be seen to occur at slightly lower manifold-depressions.

Fig. 10 shows the application of these formulas in calculating the variation of the critical and maximum pressures with change of compression ratio at full throttle at a manifold temperature of 77 deg. fahr. The substitutions in the equation are not included, nor are these results checked by actual runs. To the left of the point of intersection lies the range of compression-ratio for normal combustion; as the ratio increases beyond this point, detonation becomes more and more intense. It is obvious that the above variation is due almost entirely to the increase of maximum pressure with increasing compression ratio.

The curves of Fig. 11 show the calculated variation of critical and maximum pressure with changing mixture-ratio. As in the case of the compression-ratio chart, the substitutions are not included nor are the results checked by actual runs. The mixture was assumed to be chemically perfect at 15 to 1. It is observed that detonation disappears gradually as the mixture gets richer. On the lean side, the available heat of the mixture drops off rapidly, thereby causing a corresponding rapid change toward normal combustion. This curve probably deviates considerably from the actual relationship, due to the fact that the constant of the reaction velocity of combustion undoubtedly is reduced by the presence of excess fuel and also to the fact that the chemically perfect mixture that has been assumed to liberate a maximum amount of energy, probably does not do so, the maximum energy liberation occurring more nearly at 12 to 1 than at 15 to 1. However, the curve shows in a qualitative way the relationship existing between knock and mixture-ratio, and indicates the major factors involved. Fig. 12 records the physical characteristics of the kerosene used in all runs.

[1] A rational expression for this quantity has also been derived but is omitted here because of its complicated nature. The use of the much simpler approximate form has been found to introduce inconsiderable error.

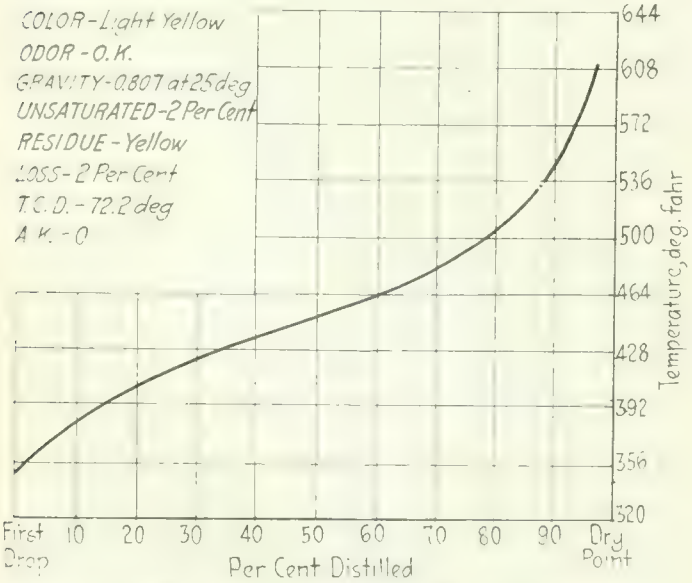


FIG. 12—DISTILLATION CURVE AND PHYSICAL CHARACTERISTICS OF THE KEROSENE USED IN ALL OF THE TEST RUNS

APPENDIX 1.

BASIC EQUATIONS

The basic equations upon which this development depend are mentioned in the text of the paper.

$$P_1 - P_2 = W^2/g(V_2 - V_1)$$
$$W = KD_1^n T_1^m \qquad (2)$$

where

D_1 = the density ahead of the flame-front
$g = 32.2$
m = an exponent to be determined experimentally
n = an exponent to be determined experimentally
P_1 = the pressure ahead of the flame-front, in pounds per square foot
P_2 = the pressure to the rear of the flame-front, in pounds per square foot
T = the absolute temperature ahead of the flame-front
V_1 = the specific volume ahead of the flame-front, in cubic feet per pound
V_2 = the specific volume to the rear of the flame-front, in cubic feet per pound
W = the reaction-velocity, in pounds of gas entering the flame-front per second

Our object is now to combine both of these equations into a single fundamental expression containing P_1 and P_2 as the only variables. This derivation will be followed readily if the two parts, W^2/g and $(V_2 - V_1)$ be developed separately.

In regard to the development of the first part, W^2/g, since the compression of the unburnt gas ahead of the flame-front can be assumed to be substantially adiabatic.

$$\frac{D_1}{T_1}\frac{D_0}{T_0} = \frac{V_0}{V_1} = \frac{(P_1/P_0)^{1/y}}{(P_1/P_0)^{(y-1)/y}}$$

where

D_0 = the density at ignition
T_0 = the absolute temperature at ignition
P_0 = the pressure at ignition
$y = C_p/C_v = 1.35$

then

$$W = KD_1^n T_1^m$$
$$K[D_0^n (P_1/P_0)^{n/y}][T_0^m (P_1/P_0)^{m(y-1)/y}]$$
$$KD_0^n T_0^m (P_1/P_0)^{[n+m(y-1)]/y}$$

and

$$W^2/g = (K^2 D_0^{2n} T_0^{2m}/g)(P_1/P_0)^{2[n+m(y-1)]/y}$$
$$= LP_1^Q \qquad (3)$$

where

$$L = K^2 D_0^{2n} T_0^{2m}/gP_0^Q$$
$$Q = 2[n - m(y-1)]/y$$

The following derivation of a value[1] for $V_2 - V_1$ is based on the assumption that the expansion of the gas

in passing through the flame-front is equal to that which would result from the liberation of the same amount of heat during combustion at a constant pressure equal to the pressure at the rear of the flame-front.

For constant pressure burning

$$h = C_p(T_2 - T_1)$$
$$= (C_p - R)(P)(V_2 - V_1)$$

where

$C = hR/C_p$

C_p = the specific heat at constant pressure

h = the effective heat value per pound of gas

$R = 778(C_p - C_v)$

hence

$$V_2 - V_1 = hR/C_pP$$
$$= C/P$$

and, in this case,

$$V_2 - V_1 = C/P_2 \qquad (10)$$

By substituting the derived equivalents for (W^2/g) and $(V_2 - V_1)$, already stated, in the basic equation $P_1 - P_2 = (W^2/g)(V_2 - V_1)$, we obtain

$$W^2/g = LP_1^Q \qquad (3)$$
$$V_2 - V_1 = C/P_2 \text{ (Approximate)}$$

then

$$P_1 - P_2 = W^2/g(V_2 - V_1)$$
$$LP_1^QC/P_2$$
$$= MP_1^QC/P_2 \qquad (5)$$

where

$$M = LC$$

APPENDIX 2

Determination of Critical Pressure of Detonation

If $P_1 - P_2$ be plotted against P_2 in equations (4) and (5) it is found that P_2 reaches a maximum value corresponding to the critical pressure of detonation. Therefore, if, in these equations, $P_1 - P_2$ be differentiated with respect to P_2 an expression may be derived defining this critical point.

$$P_1 - P_2 = (LP_1^Q \times C)/P_2$$
$$= MP_1^Q/P_2$$

where

$$M = L \times C$$

Let

$$P_1 - P_2 = z$$
$$P_2 = x$$

then

$$z = [M(x + z)^Q]/x$$

or

$$x = [M(x + z)^Q]/z$$

Differentiating

$$dx = \frac{MzQ(x+z)^{Q-1}dz - M(x+z)^Q dz}{z^2} + MQ(x+z)^{Q-1}dx$$

$$dx\left[1 - \frac{M}{z}Q(x+z)^{Q-1}\right]$$
$$= dz\left[\frac{M}{z}Q(x+z)^{Q-1} - \frac{M}{z^2}(x+z)^Q\right]$$

$$\frac{dx}{dz} = \frac{\frac{M}{z}Q(x+z)^{Q-1} - \frac{M}{z^2}(x+z)^Q}{1 - \frac{M}{z}Q(x+z)^{Q-1}}$$

x is a maximum when $\frac{dx}{dz} = 0$

Let

$$\frac{M}{z}(x+z)^{Q-1}\left[Q - \frac{x+z}{z}\right] = 0$$

then

$$\frac{M}{z}(x+z)^{Q-1} = 0$$
(indeterminate)

or

$$Q - (x+z)/z = 0$$
$$z(Q-1) = x$$
$$z = x/(Q-1)$$

Substituting in the original equation we have

$$z = [M(x+z)Q]\ x$$

$$\frac{x}{Q-1} = \frac{M\left(x + \frac{x}{Q-1}\right)^Q}{x}$$

$$x = \sqrt[Q-2]{\frac{(Q-1)^{Q-1}}{MQ^Q}}$$

or

$$P_2 = \sqrt[Q-2]{\frac{(Q-1)^{Q-1}}{MQ^Q}}$$

where

C_p = the specific heat at constant pressure

C_v = the specific heat at a constant volume

D_o = the density at ignition

$g = 32.2$

h = the effective heat-value per pound of mixture or the product of the pounds of fuel per pound of mixture times the heat value per pound of fuel times the efficiency of combustion times

$$\left[\frac{1 - (Cl \times \frac{P_a}{P_o}}{CV}\right]$$

K = the constant of reaction velocity

$$M = LC = \left(\frac{K^2D_o^{2n}T_o^{2m}}{gP_o^Q}\right) \times \frac{hR}{C_p}$$

m = an experimentally determined exponent

n = an experimentally determined exponent

P_o = the pressure at ignition

P_2 = the critical pressure of detonation

$Q = \frac{2}{z}[n + m(z-1)]$

$R = 778(C_p - C_v)$

T_o = the absolute temperature at ignition

Since the adiabatic compression of the unburnt gas ahead of the flame-front is really an extrapolation of the compression performed by the piston, D_o, P_o and T_o in the above formula can be taken as the condition of the mixture at the closing of the inlet-valve as well as that at the point of ignition. In this form the expression can be used more readily in calculations.

The values of m, n and Q, that were found to check the observed data, are $m = 3.22$, $n = 0.9$ and $Q = 3$. Equation (6) thus becomes

$$P_2 = 0.148/M \qquad (7)$$

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

TESTS—RELIABLE AND OTHERWISE

THE correspondence, published papers and advertising matter that come to the attention of the Research Department frequently quote laboratory tests and expressions of opinion on technical subjects that are by no means as reliable as they should be. Such instances are especially frequent in connection with reports of newly developed devices and equipment. We believe that these instances are the result of failure of some engineers to appreciate the importance of some of the factors that are essential to the securing of reliable test-results and to the deduction of reliable conclusions from them.

It would take a textbook to cover even briefly all the factors involved in the testing of appliances alone. A few of these factors, however, seem to be peculiarly subject to neglect. Nearly all of the special appliances, accessories or materials, tests of which are requested from time to time for the information of the producers, or for advertising purposes, are in a competitive position. Only rarely does an entirely new product appear, but what follows applies with almost equal force in this case also.

The usefulness or probable success of any particular product is always a matter of relative values. For instance, to know whether a new type of wheel is worth producing, we must know, not whether it is a *good* wheel, but whether it is better, or cheaper or possesses other advantages over the other types of wheel in use. Even if the product is in a new or non-competitive field, its value still depends upon its relation to other products. Failure to recognize this general fact is one of the common causes of unreliable test-results.

It is all too common an occurrence to find in print or in letters of commendation the results of tests of various appliances, made by engineers or in laboratories whose reputations carry great weight, but which tests were obviously made without adequate knowledge of other similar appliances. To take a concrete but hypothetical illustration, John Doe in charge of the Excelsior Laboratory reports as follows on the test of a vacuum cleaner:

> This cleaner weighs 41 lb.; it contains an alternating current motor which runs at 8700 r.p.m. and requires 200 watts on a 110-volt 60-cycle circuit. It produces a suction of 12 in. of water when the cleaner nozzle is closed, and moves 100 cu. ft. of air per min. when the nozzle is open. It was tested on a 6 x 9-ft. Persian rug into which had been rubbed 6 oz. of flour. The amount of flour caught after 5-min. operation by an inexperienced operator was 5½ oz.
>
> We conclude from these tests that this vacuum cleaner is a thoroughly reliable and satisfactory machine.

This report, backed by the name of John Doe of the Excelsior Laboratory, might have great weight with the public and be of commercial value to the salesmen of the device but, as there are a good many varieties of vacuum cleaner on the market that differ from this one in respect to every single item reported, this test fails to give the slightest information to the hypothetical vacuum-cleaner engineer as to the real merit of this particular machine, unless he himself knows the corresponding figures for at least a large part of the other machines on the market. John Doe would never append his name or that of the Excelsior Research Laboratory to such a test if he realized its essential unreliability as a real indication of merit.

Another less obvious but perhaps more important fault in many test-results is failure to take account of essential principles. When an inventor presents a perpetual-motion machine, and calls it such, he gets no hearing, but there are scores of perpetual-motion machines presented with such confusion of detail that occasionally some engineer is tricked into making a report on some of them without realizing that it violates the principle of the conservation of energy.

But there are other principles as important and fundamental as the latter, the application of which would prevent many mistakes. Most of these are, or should be, familiar to all experimentalists, but the applications are not always obvious. For instance, Newton's law, stated briefly, that "action and reaction are equal and opposite," applied to the simple case of a shaft implies that the torque on the driven end cannot exceed that on the driving end. And this is true even if the shaft is cut in two and any sort of a mechanism interposed between the ends, so long as this mechanism has no reactions on anything but the shaft itself. Yet we find every little while a new discussion or a test of some sort of transmission that obviously violates this principle and therefore cannot possibly do what is claimed for it.

One of the most conspicuous faults of test results is, too many variables changed at the same time. In its worst phases, this practice represents actual fraud. For instance, the enthusiastic purveyor of some gasoline-improver, or of a device for improving carburetion, makes a test for mileage with a second-hand car *as is*, or even guesses at the probable mileage of such a car, then he puts in his "dope" or installs his device, readjusts the carbureter, and perhaps scrapes carbon, grinds valves and does a few other things of the same kind, after which he compares the new mileage with the old. No reputable engineer would do quite this, yet it is all too common to find tests run by University laboratories or by engineers who have not seen the importance of controlling and checking test conditions so that results are really comparable.

What should have been done in the test just mentioned is this: the car should have been reconditioned first; then several tests should have been run alternately with and without the new dope or device, taking care that weather, road and driving conditions were substantially constant. The methods of using blank or check tests are too familiar and too numerous to mention here, but the frequency with which they are neglected constitutes a severe criticism of the common test-procedure.

There has been much justified criticism of tests, more particularly of those run in the laboratory, to the effect that they do not represent actual service conditions. It is usually possible with sufficient skill, experience and laboratory equipment to run almost any test in the laboratory that can be run in service and to get results that check service conditions. It is also possible, usually, to get results under service conditions that have most of the reliability and accuracy of laboratory results, provided enough skill and equipment are at hand. Sometimes one method and sometimes the other is easier, but to be sure that the results are at the same time accurate, reliable and representative of actual service is one of the most difficult phases of test procedure.

When a University or private laboratory, or a consulting engineer, makes a report on any test whatever, such a report, of course, carries weight in proportion to the reputation of the man or institution whose name is attached to it. In the

case of laboratories, such reports, although made and signed by an individual, still carry weight, depending on the laboratory's reputation.

The observations that led to this discussion have convinced us that no laboratory should allow test reports to go out, in the name of the laboratory or of any individual, without a careful check as to their reliability. Both the laboratory and the individual engineer who reports the results of tests, either by publication or in private, are under an obligation to the engineering fraternity, to the public and to the parties for whom tests were made to see that unreliable and misleading results are avoided so far as is possible.

A SURVEY OF CURRENT LITERATURE

THE RESEARCH staff of the Society regularly reviews more than 80 publications, American and foreign, bearing on the automotive industry. The articles summarized and indexed below were selected because of their probable interest to readers who do not have access to more than a few publications in the automotive field.

The Research Department invites inquiries from members who may be interested in any of the topics discussed here. Copies of all articles, clippings and pamphlets mentioned are kept on file for the information of our members.

Gasoline Specifications Revised

The latest revisions of the Federal Specifications for Motor Gasoline and other petroleum products appear in Technical Paper No. 323 of the Bureau of Mines, published by the Government Printing Office, City of Washington; price, 10 cents.

The outstanding change is in automobile gasoline, for which the latest specifications read as follows:

PROPERTIES AND TESTS

Color—Method 10.1. The color shall not be darker than No. 16 Saybolt

Corrosion Test—Method 530.21. A clean copper strip shall not be discolored when submerged in the gasoline for 3 hr. at 122 deg. fahr.

Distillation Range—Method 100.11. When the first drop has been recovered in the graduated receiver, the thermometer shall not read more than 55 deg. cent. (131 deg. fahr.) . . . (The former specification was 60 deg. cent. or 140 deg. fahr.). When 20 per cent has been recovered in the receiver, the thermometer shall not read more than 105 deg. cent. (221 deg. fahr.). When 50 per cent has been recovered in the receiver, the thermometer shall not read more than 140 deg. cent. (284 deg. fahr). When 90 per cent has been recovered in the receiver, the thermometer shall not read more than 200 deg. cent. (392 deg. fahr.). . . . (Former specification was 190 deg. cent. or 374 deg. fahr.). The end-point shall not be higher than 225 deg. cent. (437 deg. fahr.). At least 95 per cent shall be recovered as distillate in the receiver from the distillation.

High-Speed Oil-Engines

A paper by J. L. Chaloner, published in preprint form by the Institution of Automobile Engineers under the above title, in February, 1923, emphasizes the technical characteristics of the high-speed oil-engine when applied to the automobile. The paper is reviewed in *Engineering* (London) as follows:

> The author classifies the different types of engine in accordance with their fundamental principles of operation, and finds it possible to do so without introducing names of inventors or firms into the nomenclature. The main part of the paper is devoted to consideration of the design of complete engines or of mechanical details, thus presenting in a handy form a large collection of matter of great interest to the designer. Tables giving the leading particulars of numerous engines, together with data as to their performances, and, in many cases, their respective heat-balances, add to the value of the paper. Mr. Chaloner concludes by appealing for a simple system of nomenclature based on the technical characteristics of the various classes of oil engine, so that the name would define the type of engine and avoid the confusion at present existing. He considers that the limiting dimensions of the present type of engine are well known, being controlled by mechanical and metallurgical properties of the materials employed. No system of fuel utilization which yields a maximum possible return of only 50 per cent will remain satisfactory to engineers, and Mr. Chaloner appears to envisage the future discovery of some new and more efficient cycle for internal combustion.
>
> However this may be, the modern internal-combustion engines are at present the most efficient machines known for converting fuel energy into work, and the author's review of those using oil as fuel is a most useful contribution to the literature of the subject.

The Technique of Calculation

A review of James Watt's paper, Automobile Calculations, appeared in the December, 1922, issue of THE JOURNAL. In this paper the author suggested practical methods by which certain characteristic problems could be tackled. His primary object in writing the paper was to afford assistance to those personally responsible for carrying out the calculations. A supplementary paper, under the above title, that has been prepared chiefly for the benefit of those responsible for the organization and supervision of such work, appears in the *Automobile Engineer* for February, 1923, p. 59.

Some Interesting Gaging Appliances

A number of novel and effective machines for Gear Inspection and Piston-Ring Testing are described and illustrated in *Engineering Production* for Jan. 15, 1923. One of them is the Saurer piston-ring testing apparatus for verifying the pressure exerted by the rings when compressed. Another appliance, designed for testing spur gears for the pitch and the distance between the centers of the wheels, and an apparatus for checking accurately the play of the teeth and the concentricity of the gear wheels, are likely to be of interest to many of our readers.

Aeronautical Nomenclature

To insure greater uniformity and accuracy in official documents and in trade and technical publications dealing with aeronautical subjects, a special conference authorized by the National Advisory Committee for Aeronautics prepared Report No. 157, which was issued under the above title. The report is divided into three sections: Alphabetical Nomenclature, Nomenclature by Divisions and Aeronautical Symbols. The subject is covered thoroughly in this timely publication.

Notes on Aerodynamic Forces on Airship Hulls

The failure of the airship ZR 1 a disaster that is still fresh in most minds, was probably due to a lack of knowledge of this particular problem, which has been worked out mathematically by the author, L. B. Tuckerman, engineer physicist of the Bureau of Standards. The article appears as No. 129 of the Technical Notes of the National Advisory Committee for Aeronautics.

High-Speed Engine Indicators

The problems of the engine indicator are covered very thoroughly in four papers read before the British Institution of Mechanical Engineers, Jan. 19, 1923, and published in *Engineering* for Jan. 26, 1923. These papers and the dis-

cussion that followed them are reviewed critically in *Engineering* for Feb. 16, 1923, attention being drawn to the Midgley indicator that was not mentioned at the meeting, but which possesses one or two special features that meet points of criticism raised by various speakers.

Multi-Wheel and Track Motor-Vehicles

T. G. Tulloch, in a paper issued by the Institution of Automobile Engineers as preprint, in March, 1923, discusses the following factors in the economics of land transportation other than by railroad: reduction in the cost and the maintenance of roads; reduction in the taxation of the vehicles; increases in the carrying capacity of the roads; increase in the carrying capacity of the vehicles; increase in the speeds; reduction in the running costs and the maintenance of the vehicles; influence on future wars.

Torsion of Crankshafts

S. Timoshenko in *Mechanical Engineering* for February, 1923, considers the case of a crankshaft with a single throw and establishes the mathematical relations for such a case. He investigates three conditions for such a crankshaft: (*a*) no constraint, corresponding to ample clearance in the bearings; (*b*) complete constraint, corresponding to no clearance in the bearings; (*c*) partial constraint, corresponding to ample clearance in the halves of the bearings nearest the web and no clearance in the other halves.

Effect of Repetition Stresses on Materials

The efforts made by research workers during the past few years to determine the fatigue range of materials, and to estimate the conditions that determine failure under repeated stresses illustrate the growing importance of these problems to engineers. In a paper read before the Institution of Civil Engineers, at Birmingham, Prof. F. C. Lea discussed these questions in the light of recent experience. The work of H. F. Moore and J. B. Kommers on the Fatigue of Metals, published as a University of Illinois Bulletin, No. 124, in 1921, covers some of the points discussed in Professor Lea's paper. The results of repeated stress tests of various materials at various temperatures are given in tabular form in this interesting paper, which appeared in *Engineering*, Feb. 16, 1923, p. 217, and Feb. 23, 1923, p. 254.

Gearboxes for Motorcycles

A paper by I. Cohen that was issued by the Institution of Automobile Engineers as a preprint in March, 1923, contains a critical study of the design and construction of motorcycle gearboxes, gears and clutches.

A Comparative Test

The *Autocar* in its issue of Feb. 16, 1923, pp. 252-255, presents the results of a comparative test of a Peugeot 15-hp. four-stroke four-cylinder gasoline engine and a Peugeot-Tartrais 15-hp. two-stroke two-cylinder heavy-oil engine.

Non-Skid Tire-Tread Design

H. W. Perry in *India Rubber World* for March 1, 1923, discusses the principal requisites of a superior design which are stated as resistance to side-slip and spinning; resistance to wear; freedom from suction and noisiness; attractive appearance and distinctiveness.

Burnishing the Teeth of Gears

In an article in the *American Machinist* for March 1, 1923, Ellsworth Sheldon describes a process that corrects minor errors of contour, smooths and densifies tooth surface, forestalls effects of distortion in hammering; analogous to cold-hammering.

The Oscilloscope

Engineering Production (London), Nov. 16, 1922, contains notes on a new and useful optical mechanical device with many applications to automotive engineering work.

TEST OF AIR-CLEANERS FOR TRACTOR ENGINES

A REPORT on the performance of 26 air-cleaners for tractor engines was presented before the American Society of Agricultural Engineers by A. H. Hoffman, who made the tests and developed an accurate laboratory method for determining dust-separating efficiency. This method, which makes possible a reliable comparison of the cleaners, requires a standard air-floated dust, which can be kept in an unchanged condition indefinitely. This dust is fed to all cleaners in the same manner and at the same rates by an ingenious dust-feeding mechanism. A known weight of the dust is mixed with the air entering the cleaner to be tested; the dust not retained by the cleaner is removed by an "absolute cleaner" that is designed so that the dust collected by it can be weighed accurately or compared photographically.

The efficiencies thus determined for nine oil-type cleaners range from 94.7 to 99.9 per cent; for the nine water-type cleaners, from 83.6 to 97.3 per cent; and for eight dry-type cleaners, from 37.6 to 99.5 per cent. Each cleaner was subjected to at least three test-runs, during which it was connected with the 1½-in. Kingston model-L carbureter of a Weidely Model MAU engine of 22.5 rated hp. The normal engine-speed was kept at 1200 r.p.m., and the dust was fed at the rate of 50 grams in 30 min. The three test-runs were made respectively under normal load of 20.4 hp., under light load of 12.6 hp., and under service conditions of variable load, variable speed, quick pick-up with wide-open throttle, idling and backfiring. The service test showed lower efficiency for a number of cleaners.

The dust-separating efficiency, although the most important feature, is not alone sufficient to determine the relative merits of cleaners. Thus, the vacuum at the carbureter intake due to the attached cleaner may affect the power of the engine, especially when the cleaner becomes filled with dust and dirt. A series of power determination with and without cleaners attached seemed to indicate that this effect is slight so long as the cleaner has collected but little dust. As the cleaner fills-up, however, the vacuum increases very fast with some cleaners, but not with others. In this respect the water-type cleaners showed the best performance, for in all nine of the water-type cleaners under the test the vacuum was independent of the amount of dust collected. Of the nine oil-type cleaners, four showed a vacuum proportional to the amount of dust collected; the same was true of one of the eight dry-type cleaners. This "fill-up" test was designed to exhibit the ability of the cleaner to work under gross neglect and abuse. In a general way the results give some idea of what might be expected of the cleaner when given no attention until it is filled up with dirt. When a cleaner under this test book 5 lb. or more of the dust without an appreciable rise in the vacuum and without loss of dust-separating efficiency, it was considered that the particular cleaner's ability to stand neglect has been established satisfactorily.

A number of the cleaners had intakes that were not screened properly and their construction was such that the presence of vegetable refuse might affect the vacuum. These cleaners were put to a special test, in which air-dried wheat chaff was sifted into the airstream and vacuum readings taken. Finally, the water-type cleaners were intercompared for performance when the water-level was low. Both of these special tests revealed cleaner characteristics that were not indicated by the dust-separating efficiencies.

Mr. Hoffman's tests constitute the most comprehensive study of air-cleaners that has ever been made, and the details of the tests, now on file in the office of the Agricultural Engineering Division, University Farm, Davis, California, may be studied profitably by everyone interested in tractors. The results of the tests will be published in a forthcoming volume of the *Transactions of the American Society of Agricultural Engineers.*

A Critical Study of Modern Automotive-Vehicle Steering-Systems

By Herbert Chase[1]

Annual Meeting Paper *Illustrated with* Drawings

STATING that automotive literature presents surprisingly little helpful information concerning the faults of the steering-systems used on automotive vehicles and that, in spite of the fact that so many of the faults are self-evident, they frequently are overlooked in actual practice, the author includes with the presentation of his own investigations summaries of the views expressed by numerous well qualified automotive engineers and discusses these steering-gear faults in some detail.

Beginning with the subject of safety, consideration is given successively to the causes of hard steering, the angular position of knuckle-pivots, knuckle-pivot location, the foregather or toe-in of wheels, castering or trailing effect, wheel-wabble, drag-link location, irreversibility, steering-gear type comparisons, tie-rods and tie-rod arms. Numerous drawings illustrative of present-day practice are presented and commented upon, reference being made also to other articles, printed previously, that are pertinent.

STEERING-SYSTEMS employed on many modern passenger-cars and trucks are known to have certain faults, but the literature of the automotive industry contains surprisingly little helpful information regarding either these faults or the factors that should control the design of the system as a whole. Neither the Transactions of the Society nor the *Proceedings* of the British Institution of Automobile Engineers contain any papers dealing with the subject except by incidental or casual reference. It has, therefore, seemed highly desirable to collect here certain data pertaining to various parts of the system, and to discuss the arguments advanced for the several types of construction employed and their layout or arrangement in reference to other parts. The effect upon the operation and performance of the vehicle will be considered also.

No claim for originality in the material presented is made. Many of the facts given can be said to be virtually self-evident, yet it is surprising how frequently they are overlooked in actual practice. I have been assisted greatly in preparing the paper by several members of the Society. In fact, the views expressed are formulated largely by summarizing the opinions of a number of well-qualified engineers, including several of those most prominent in the automotive industry.

Steering-systems as a whole have been changed but little for many years. The conventional layout has operated with reasonable satisfaction in most cases; so, it has been given relatively little attention as compared to other parts of the chassis that demanded intensive development. As a result, the steering-system has lagged behind in the general development of motor vehicles. It is hoped that the data assembled in this paper will encourage further study of the subject and result ultimately in a decided improvement in steering systems.

Safety

It may seem almost superfluous to discuss the matter of safety as affecting steering-system design, but the fact is that far too little attention has been given to this factor, which should be the primary consideration in the design of most parts of every self-propelled vehicle. Important details, such as means for locking the yokes properly to the tie-rod, are overlooked too frequently. Lost motion that results at this and other points frequently makes the vehicle unsafe. I know of instances where it has been necessary to braze the yokes and the tie-rod together before the joint would remain tight. Serious accidents are said to have resulted from failure to give attention to items of this character. One manufacturer of steering-gear parts states that some automotive manufacturers refuse to accept parts in which the limits are held sufficiently close to insure good fits, simply because such parts cannot be assembled so rapidly as others that are given more clearance. A policy of this character is certainly not in the interest of safety and, therefore, cannot be criticised too severely. Other points in the steering-system are open to similar criticism. When one stops to realize the importance of safe steering-systems, especially under modern conditions of traffic congestion, it is evident at once that no pains should be spared to make the steering-system safe. What user would not gladly pay a few dollars more for a car with a safe system than for one having a steering-system open to criticism in this respect?

I shall refer only to the conventional steering-system in which the two front wheels are mounted on spindles attached to the axle by pivoted knuckles so that their angular position is controlled by a steering-gear connected to the knuckles by a drag-link and tie-rod.

It is desirable, manifestly, to layout such a system in a manner that will permit all four wheels of the vehicle to turn about a common center without any sliding action when the vehicle turns a corner. To meet this condition, it is necessary that the horizontal projection of the axes of all four wheels meet at a common point in all positions of the wheels. To fulfill it exactly would require that the locus of the point of intersection be a straight line coinciding with the axis of the rear axle, a condition that cannot be met precisely with the conventional linkage. It is fulfilled approximately when the arrangement is such that the horizontal projection of lines drawn through the centers of the knuckle-pivot and the eyes or balls on the arms to which the tie-rod is attached meet in the central vertical plane of the car at or slightly forward of the center of the rear axle. Articles[2] by J. L. Napier, discussing the geometry of this layout, have appeared in the technical press. Unless this rule is followed, excessive tire-wear and hard steering are apt to result.

[1] M.S.A.E.—Engineering editor, *Automotive Industries*, New York City.

[2] See *Automobile Engineer*, July, 1910, p. 35; see also the Gasoline Automobile, by P. M. Heldt, vol. 2.

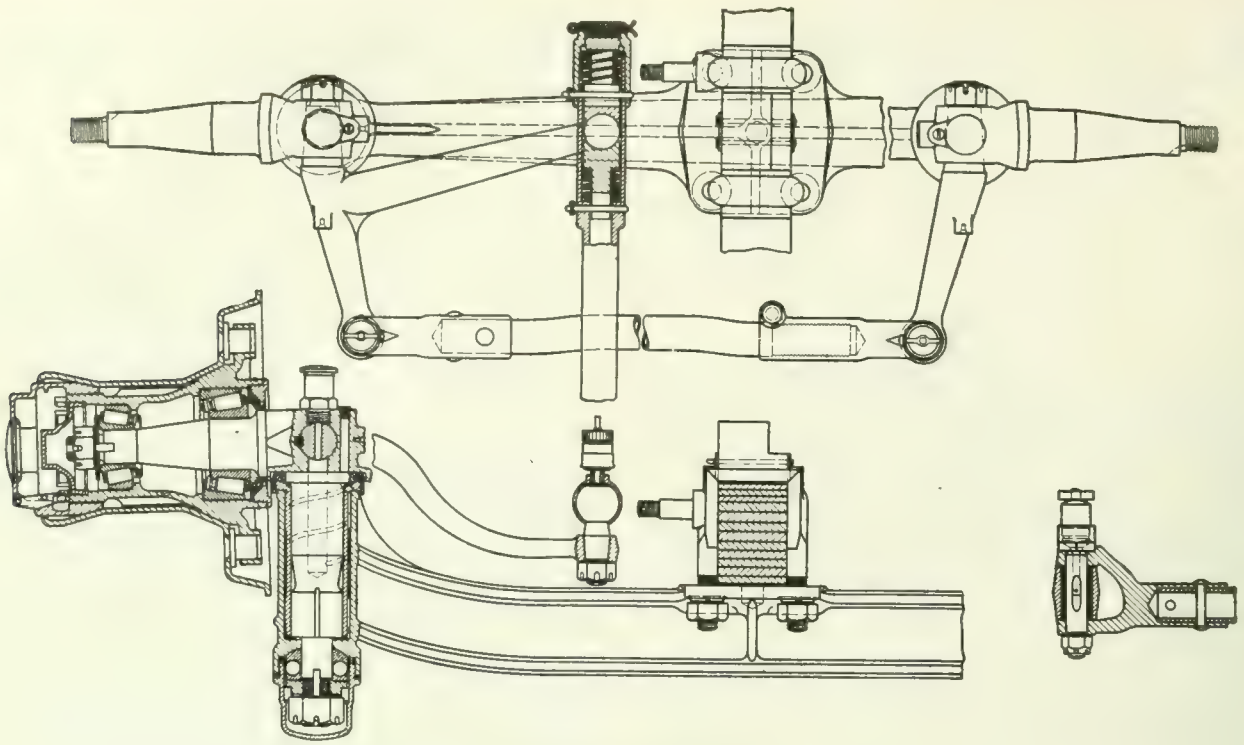


FIG. 1—THE KNUCKLE-PIVOT DESIGN OF STEERING-MECHANISM USED ON THE MARMON CAR

CAUSES OF HARD STEERING

Among the common faults of the steering-system is the excessive effort required in its normal operation. The primary causes of hard steering are friction and faulty design of the system, the latter frequently resulting in the former. Friction can, of course, occur at many points and for a great variety of reasons, some of which will be enumerated.

(1) Inaccurate machine work at joints and bearing surfaces
(2) Careless assembly, often resulting in lack of alignment
(3) Insufficient lubrication
(4) Failure to exclude dirt and moisture
(5) Excessive bearing pressures
(6) Under-inflation, condition, type and construction of tires
(7) Faulty design

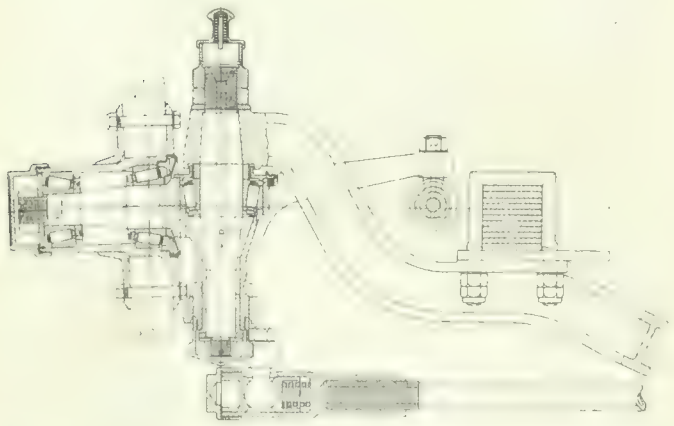


FIG. 2—THE LATEST CRANE DESIGN OF STEERING-KNUCKLE WHICH INCORPORATES A VERTICAL PIVOT WITH A ROLLER THRUST BEARING AND A WELL THAT PERMITS ALL BEARINGS TO BE KEPT IN A BATH OF OIL

Under (1), nearly all parts of the steering-gear can be cited; the balls and the sockets in the drag-link, the king-pins and their bushings and the tie-rod joints. It is not contended that these units are always subject to faulty machine work, but instances in which they have given trouble on this account are fairly common.

Numerous examples of careless assembly (2) occur.

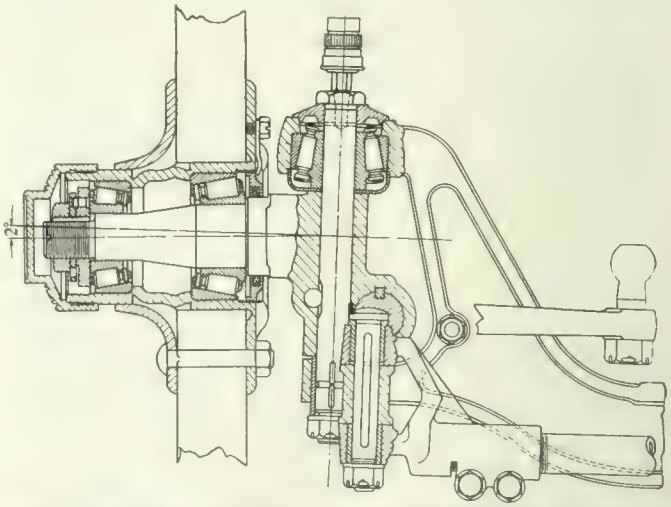


FIG. 3—THE TIMKEN AXLE EMPLOYING A ROLLER THRUST BEARING

A common one is the fitting of the steering-column in the support at the dash. This is sometimes sprung into place after the lower end of the gear is bolted in position, with results that obviously are poor. Another is the forced fitting of the king-pins and a third is the use of excessive spring pressures on drag-link and tie-rod bolts.

Insufficient lubrication (3) is so common a fault, especially at the king-pins and at drag-link and tie-rod joints, that these parts wear rapidly and often rust. The steering-gear usually is filled originally with heavy oil that fulfills its purpose well so long as it remains in

place, and the same can be said of the knuckle-pins on a few cars. Excellent examples of good construction in this respect are the Marmon and Crane designs shown in Figs. 1 and 2. In both of these the bearing surfaces are arranged so as to be submerged in a well of oil. The only place for the oil to escape is at the top of the wells, where felt washers are fitted. In the Crane design the aim is to maintain a small head of oil above the bearings. The use of a hair filling in the oil reservoir helps by its capillary action to prevent loss of oil at the top of the well. The arrangement is such that no gun is required for renewing the oil supply. While this Crane design is still in the experimental stage, it appears to have much to commend it.

Several of the designs show good examples of the use of ball thrust-bearings for supporting the weight of the car; while the Crane design, Fig. 2, and the Timken design, Fig. 3, the latter being used on Dorris and other cars, illustrate the use of roller-type thrust-bearings. Such bearings, if well protected from dirt and water, undoubtedly have much to commend them, and should help greatly in minimizing friction. Another and rather

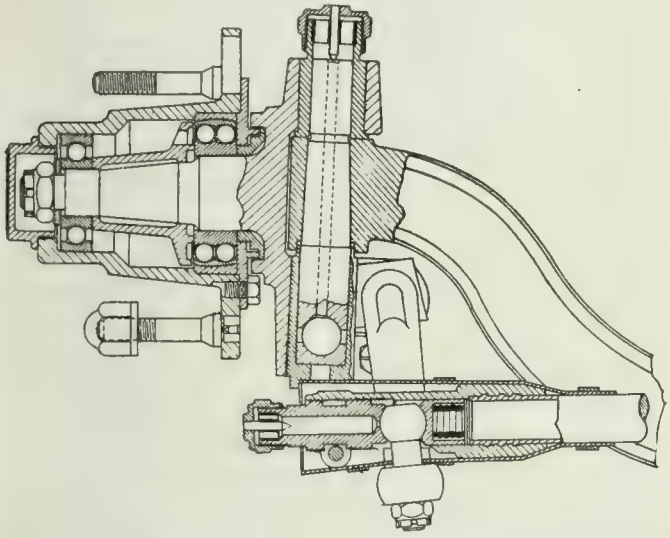


Fig. 4—The Steering Knuckle of the Protos Car in Which a Single Large-Diameter Ball Serves as the Thrust Bearing

novel form of thrust bearing consisting of a single large ball is used in the knuckle of the German Protos car, as shown in Fig. 4. This arrangement appears to have the advantage of simplicity and moderate cost.

Anti-friction bearings, of both the ball and the roller types, are frequently used in the steering-gear, especially to take thrust but also for radial loads. The Marmon and Vauxhall gears, shown in Figs. 5 and 6, furnish examples in this connection. Such bearings certainly help to minimize friction, but they have certain disadvantages in respect to higher first-cost. In some cases they are subject to a hammering action, especially when solid tires are employed, which is destructive and may cause corrugating of the bearing surface, particularly if the loads are heavy.

Lubrication of drag-link and tie-rod joints is usually a decidedly hit-and-miss factor, and is seldom given sufficient attention when it depends upon a hand operation. An excellent design is one in which the ball joints are made as nearly oil-tight as possible, and the tube filled with oil which keeps the ball surfaces well lubricated. A design of this character is said not to require attention oftener than once in 6 months. Other points that frequently cause excessive friction are the bearings in the

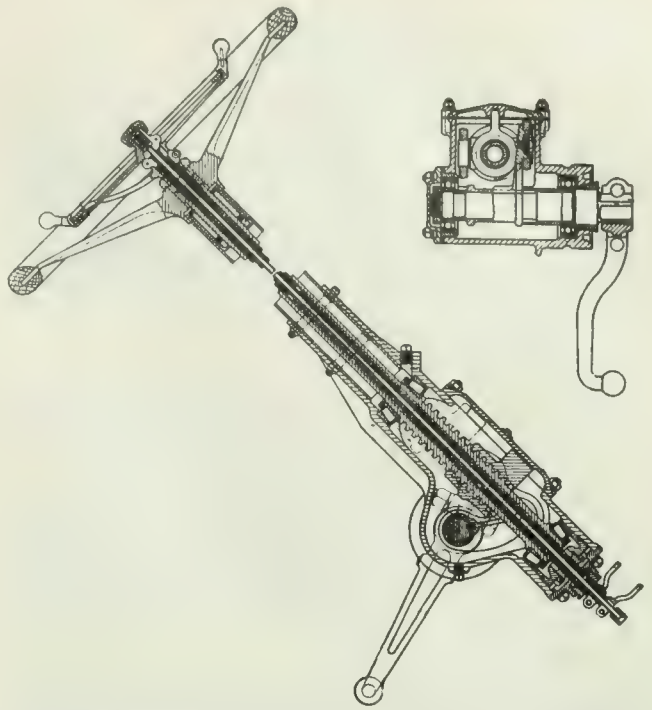


Fig. 5—The Marmon Steering Gear in Which Anti-Friction Bearings Are Used in the Steering Column and on the Steering-Lever Shafts

steering-column. They are apt to be overlooked when lubrication of other parts is given attention.

Failure to exclude dirt and moisture (4), especially at drag-link, tie-rod and knuckle-joints, naturally results in excessive friction and rapid wear. Provision for adequate lubrication at all times, by means that tend to force dirt out of rather than into bearings, is a kind of antidote, partly because a good lubricant properly applied tends to prevent rust and foreign matter from accumulating on the bearing surfaces, and partly because the constructions that keep the lubricant in place frequently are fully as effective in excluding dirt. A ball-and-socket joint properly enclosed has certain advantages over the yoke-and-pin type in respect to the facility with which lubricant can be kept on the surfaces, as well as in freedom from rattle or binding, one of which defects is almost certain to occur with the conventional yoke and pin.

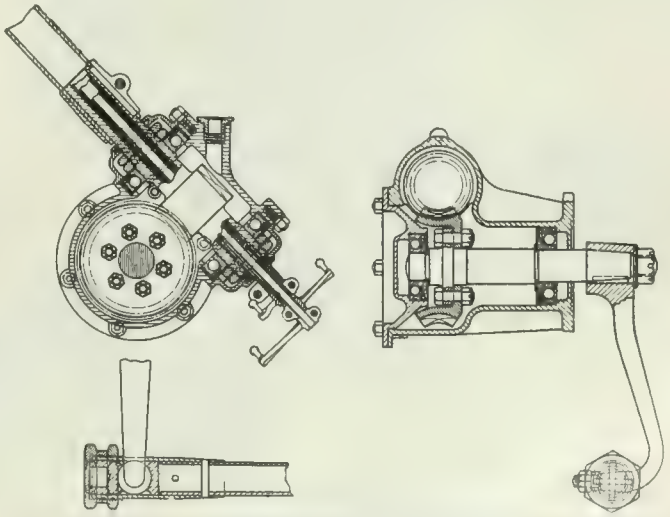


Fig. 6—Another Example of the Use of Anti-Friction Bearings, the Vuxhall Steering Gear

Excessive bearing pressures (5) are very common in nearly all parts of the steering-system. They are, in fact, difficult to avoid within the limits of weight and size usually imposed. It is impossible to consider many details of specific designs here, but it can be said that pins of larger diameter with longer bushings often are applied easily. For example, in the case of one light American car, the 1923 model will have the following changes in this connection, as compared with the 1922 model. The king-pin diameter will be increased from $\frac{5}{8}$ to $\frac{3}{4}$ in.; the bushings in the axle yoke will be $\frac{1}{4}$ in. longer; the tie-rod pins will be increased from $\frac{1}{2}$ to $\frac{5}{8}$ in. and their length will be doubled.

Ease of steering is affected by tire inflation (6) condition, character and width of tread, and by the type of tire employed. One authority states that the static resistance to turning offered by a tire varies inversely as the square root of the inflation-pressure. Cord tires, because of the lower inflation-pressures employed, and the consequent greater area of tread in contact with the ground, are said to steer harder than the same nominal size of fabric tire when properly inflated; but whether this is true when the vehicle is in motion is open to some question. Pneumatic tires are said to render steering harder than solid or cushion tires.

Faulty design (7) often contributes heavily to hard steering, as will be noted from some of the foregoing items. Too small a steering-gear with insufficient leverage is one frequent fault but, of course, it is poor economy to employ a large reduction giving a great leverage simply to overcome friction which is higher than necessary, though this is sometimes done. A much more logical procedure is to minimize friction and then apply a gear with sufficient reduction to accomplish the purpose for which it is intended without requiring undue exertion upon the part of the operator.

Incorrect location of the steering-arms and distortion of various parts of the steering-system either under the load of the vehicle or under that imposed by the steering operation are other factors that frequently contribute to hard steering. Distortion often results in binding which, in turn, causes excessive friction. In some cases the pressures imposed are so heavy as to cause the oil-film to be squeezed out and the parts to seize or score. This results in a rough surface that offers increased friction and causes rapid wear.

When a yoke-and-pin construction is used on the tie-rod it is necessary, to prevent binding, to make sure that the axes of the pins are precisely parallel to the

[1] See *Automobile Industries*, Nov. 30, 1922, p. 1068.

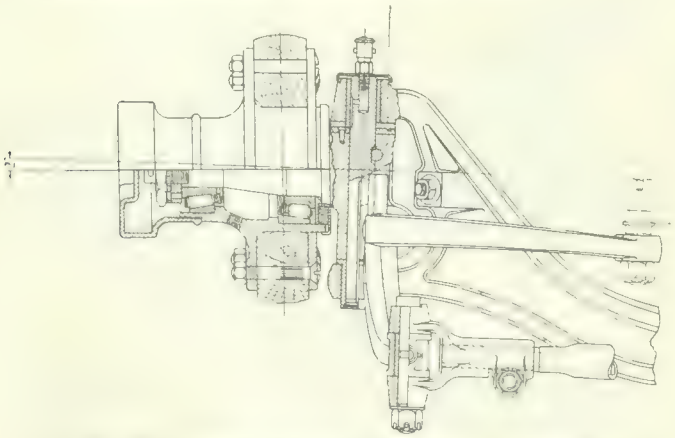


Fig. 7—The Packard Axle with a Vertical Knuckle-Pivot and Plain Bushings

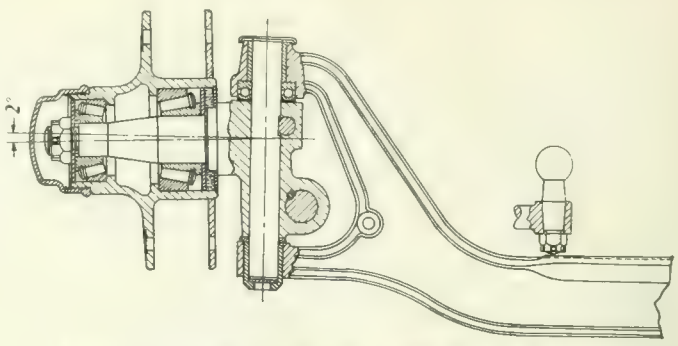


Fig. 8—The Columbia Axle-End, Another Example of the Vertical Knuckle-Pivot Construction

axes of the knuckle-pins and to each other. Careless assembly, or the load imposed upon the axle after assembly, often results in a lack of parallelism of the parts in question, with the inevitable result that excessive friction occurs. This is another reason for favoring the use of a ball and socket on the ends of the tie-rod arms.

The proper finish of bearing surfaces and a provision for adequate clearance at these surfaces seem to be obviously necessary, but they are frequently overlooked. Another item sometimes forgotten is that an inclined axis of the steering-pivot, other than one which gives true center-point steering, raises or tilts the front end of the car when the wheels are deflected from the straight-ahead position. This, of course, requires some additional effort in steering.

Other factors that contribute to hard steering are the weight on the front wheels of the vehicle, and the length of the moment-arm represented by the distance between the central point of tire contact and the point at which the axis of the knuckle-pivot, when produced, strikes the road. Other things being equal, it is desirable, in the interest of easy steering, to proportion the vehicle as a whole so as to make the load on the front wheels as small as possible. It is desirable also to keep the moment-arm referred to as short between knuckle and wheel parts as proper clearance and manufacturing conditions permit. This again may seem to be an almost self-evident fact, but it is one that sometimes is given too little consideration. One manufacturer recently showed me how this moment-arm easily could have been decreased almost 1 in., and without any increase in cost, in the case of the axle he was purchasing from a parts maker, if the designer had given proper attention to this factor in making the original layout. Additional factors that create unnecessary friction are introduced if the amount of foregather of the wheels is excessive or if the layout of the drag-link, knuckle-arms and other parts of the steering-system is not correct. The geometry of the system has been treated with reasonable thoroughness in several textbooks and in some engineering papers to which reference is made elsewhere; but it is given too little consideration, especially in the case of some cars that are assembled from units, the inter-relation of which is not given sufficient study.

In a recent article by E. M. Caskey, a steering-gear manufacturer, entitled Hard Steering as a Result of Inaccurate Manufacture and Assembly,[2] it is stated that it has proved practically impossible to build a car in such a way as to have free-steering qualities and still have good road-holding qualities at moderately high speeds. We have yet to find any engineer who agrees with this view. It is true that, in some cases, a free-steering car will bring to light faults in the steering-

system that, in a harder steering car of similar general design, would not be evident. This is due to the fact that certain inherent faults, especially the tendency to wheel-wabble, are not infrequently damped-out by friction which, if it is decreased, tends to make these inherent faults apparent; but it does not follow necessarily that easy steering and good road-holding qualities are incompatible. In fact, there is good reason to believe that, when the steering-system is designed properly and therefore is reasonably free-acting, the road-holding characteristics of the vehicle will not be impaired.

Angular Position of Knuckle-Pivots

Many characteristics of the steering-system, especially in respect to performance, are dependent upon the angular position of the knuckle-pivots. Knuckle-pivot axes as seen in front elevation usually are made vertical in the case of American cars and trucks, and the same is true of many foreign-built vehicles. Examples of the vertical pivot are the Packard axle, Fig. 7; the Columbia axle,

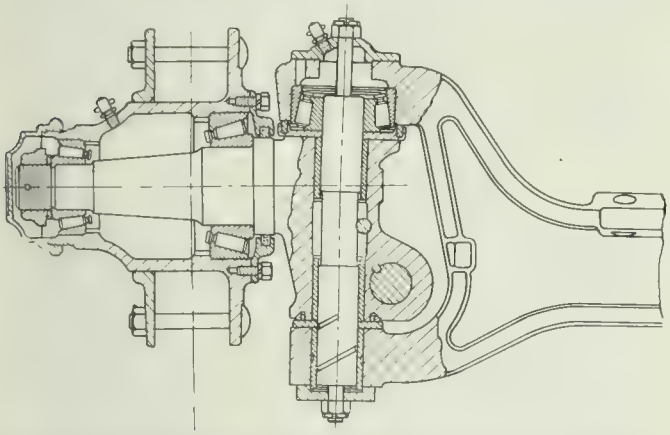


Fig. 9 The Steering-Knuckle Used on the Autocar Truck Which Makes Use of a Vertical Pivot

Fig. 8; and the Autocar truck-axle, Fig. 9. However, there are many advocates of the transversely raked pivot and, in particular, of a pivot that has its axis inclined so as to meet the road at the central point of tire contact. This type of construction, employed by Rolls-Royce, Fig. 10, and Metallurgique, Fig. 11, usually is, among others, referred to as "center-point steering" and has certain advantages that are worthy of careful consideration. These advantages include

(1) Road shocks in the plane of the wheel have a minimum moment about the knuckle-axis and, consequently, are transmitted in a less degree to other parts of the steering mechanism
(2) Wheels have a minimum tendency to toe-out, because the moment of rolling resistance about the pivot axis is at a minimum
(3) Possibly easier steering, although there is some question as to whether this actually is realized in practice

In an article by A. Ludlow Clayden, entitled Wheel-Wabble and Other Faults in the Steering-System, it is contended that advantage (1) is negligible. This contention has been refuted by O. M. Burkhardt in an article entitled Steering-System Stresses Reduced with Transversely Raked Pivots,[5] and by other persons. Road shocks on the steering mechanism undoubtedly are less by a considerable amount, but of course they are not eliminated. Some argue that, with center-point steering, the front

[4] See *Automotive Industries*, Oct. 5, 1922, p. 667.
[5] See *Automotive Industries*, Dec. 14, 1922, p. 1178.

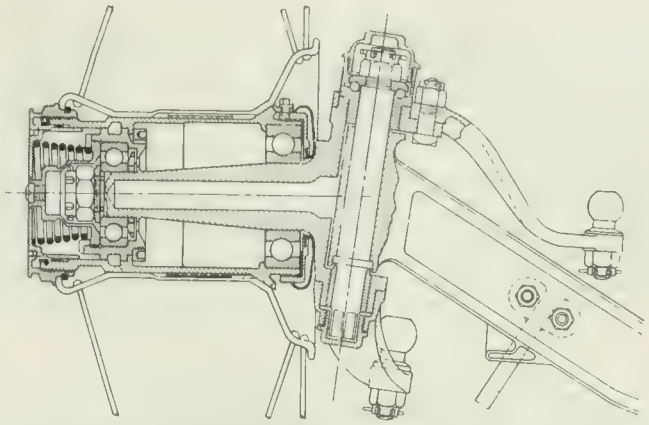


Fig. 10—The Rolls Royce Steering-Knuckle in Which the Pivot is Inclined to Give Center-Point Steering

end of the car is raised when the wheels are deflected from their straight-ahead position, a contention with which I am unable to agree. Since, with center-point steering, the wheel does not roll when it is cramped with the car standing, as it does with a vertical pivot, it seems doubtful whether a car with transversely raked pivot actually steers more easily than one with vertical pivots. With center-point steering the torsional stresses on axle and spring due to road shock are increased, but the design easily can be made such as to care for these. Clayden contends,[4] as pointed out elsewhere, that transversely inclined pivots involve an increased tendency to bring about wheel-wabble.

It undoubtedly is more difficult to manufacture axle and knuckle parts when transversely inclined pivots are employed; so, there is good reason to doubt whether, all things considered, the use of this construction is worth while except perhaps when front-wheel brakes are employed. In that case the possible stresses on the steering-gear and linkage are so great that inclined pivots are worth while if not actually essential. Examples of inclined pivots used with front-wheel brakes are shown in Figs. 11, 12 and 13, all of which are approximately or

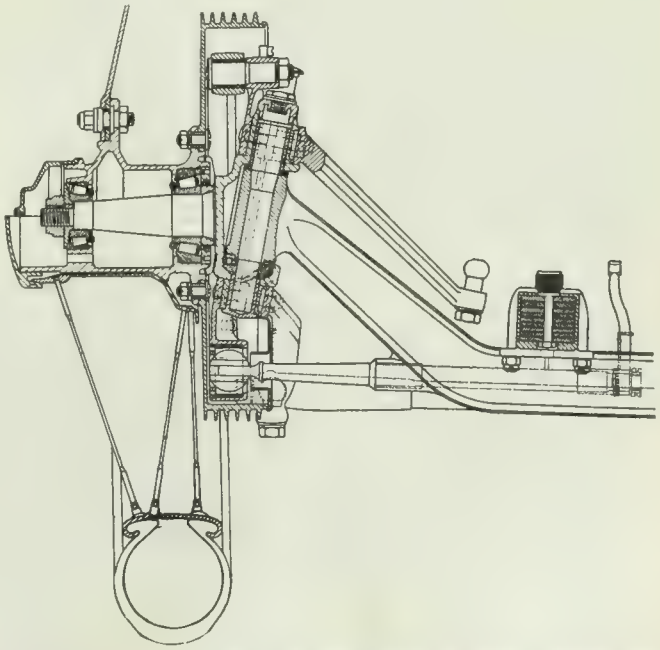


Fig. 11—A Good Example of the Knuckle-Pivot Layout Employed With Front-Wheel Brakes, That Used on the Metallurgique Car

exactly center-point arrangements. To put the matter in a somewhat different way, it can be said that it is desirable to reduce the moment of forces in the plane of the wheel about the knuckle-pivot, but that a construction which does not involve transversely raked pivots but which still reduces the moment in question a sufficient amount to be wholly satisfactory in practice is possible. Tilting the wheel spindle toward the ground helps reduce the moment, but excessive wheel-rake is not good, either from the standpoint of appearance or in respect to its adverse effect on tire wear. Angles of 1 to 3 deg. are nearly always employed and greater angles are used in some cases.

Knuckle-Pivot Location

It seems to be self-evident that it is desirable to bring the knuckle-pivot as close to the central plane of the wheel as is feasible without involving unnecessary expense, yet surprisingly little attention is given this point in some instances. In one case, that of a well-known and much-used American axle, it was found possible to bring the pivot closer to the wheel a full ½ in. by simply using countersunk hub-bolts and slightly altering the machine work on the wheel spindle. Incidentally, this simple change greatly improved the steering of the car.

Engineers who have given the matter of knuckle-pin location careful study seem to be agreed that an ideal position for the knuckle-pivot is in the central plane of the wheel. There are certain problems involved in so placing it, but they do not appear insuperable, especially for higher-priced cars and trucks. This arrangement is, in fact, used to a limited extent, and one of its advocates contends that the cost actually is less than when conventional practice is followed. However this may be, a design embodying this principle is worthy of careful consideration and easily can result in better steering qualities. The primary advantages of a construction such that the axis of the knuckle-pivot lies in the central plane of the wheel are that center-point steering is attained without a tilted pivot and all tendency toward wheel-wabble, except that caused by lack of balance of the wheel, is eliminated. The chief disadvantage of this construction, or at least that of one form which has been employed, is that unnecessarily large wheel bearings are required. This disadvantage does not apply, however, to all arrangements that embody the principle, as will be seen by reference to the drawing at the left of Fig. 14, which shows the construction employed for some time on Marmon cars but not used on later models. It will be noted that the bearings are no larger than normal, but that the wheel spindle is reversed and carried in the forked end of the front axle, the jaws of which must be somewhat deeper than those ordinarily employed.

Two other designs embodying the same principle but employing bearings that appear to be larger than those normally used are shown in the central and right-hand views of Fig. 14. These designs, due to W. J. P. Moore, embody certain advantageous features, among which may be mentioned the fact that the pivot is enclosed completely in such a way that it is well protected from the entrance of dirt or moisture and should be easy to lubricate. Also, the increased size of bearing appears to be offset to some extent by a simpler axle-end than commonly is employed.

Foregather or Toe-In of Wheels

When the design is such that the normal rolling-resistance of the wheels tends to produce moments about the knuckle-pivots, or when the wheels have undergather, one or both of which constructions are, I believe, universally employed, the wheels have a tendency to spread or toe-out. In fact, if set absolutely straight ahead with the vehicle stationary, they will toe-out more or less, depending upon the amount of play and spring in the parts stressed, and rapid tire-wear will result. To counteract this tendency, the front wheels are always set with a foregather of 3/16 to ½ in. Just how much of this foregather is eliminated due to the stresses of normal service I do not know. I have never seen data in this regard, but believe that, in most cases, the wheels are still foregathered to some extent, even at times when considerable resistance to rolling is present. Just why this should be desirable is not entirely clear, but it is supposed to add to tire life to create this condition. It can be said, however, that a tilted wheel tends to roll in a circular path instead of in a straight line, and that foregather of the wheels counteracts this tendency. There is certainly one position of the wheels at which resistance to forward motion is at a minimum. Any deviation from this position, either inward or outward, increases this resistance; so, too much foregather is as bad as having the wheels toe-out. So far as I am aware, there is no definite rule establishing the precise amount of foregather which is desirable.

Castering or Trailing Effect

When the knuckle-pivot axis is truly vertical, the vehicle has little if any sense of direction; that is, it ac[illegible]ly in response to steering forces imposed by the operator, who must usually keep feeling the steering-wheel to hold the vehicle to its course. If, on the other hand, the axis of the pivot be tilted either transversely or with its upper end to the rear, the vehicle has a certain sense of direction or self-righting tendency; that is, a tendency to straighten out when deflected from a straight course, except perhaps under certain extreme conditions. This is due to the fact that the weight supported on the pivot tends under the influence of gravity to fall to the lowest point that the mechanism permits, or to trail behind the central point of tire and road contact. This is usually termed castering action. There is still a castering action if the pivot be tilted forward, but the vertical force due to the weight of the car no longer trails behind the vertical force due to the pressure of the road against the tire. This anti-trailer effect creates a tendency for the wheel to reverse when the vehicle is in forward motion and pull the steering-wheel from the hand of the operator; it is precisely the same effect as is created by rearward motion of the vehicle when the pivot is tilted backward as in common practice, although Clayden[6] takes an opposite view.

Napier points out,[7] in his article entitled Castering Action, that there are other forces besides gravity that contribute to the castering effect when the car is in motion and the wheels are deflected from a straight course. These are centrifugal or inertia forces that depend upon the velocity of the vehicle and the radius of the curve it is describing. In respect to castering, Napier says further:

> It will inevitably be found that the greater the caster effect, the more pronounced will be the influence of each rut and bump in deflecting the car from a straight line; and a driver relying on caster effect would be ill-advised to expect his car without personal intervention to avoid the ditches, even on the straightest and widest of rough roads. It is true that, if a bump deflects the steering wheels and the car from one smooth portion

[6] See *Automotive Industries*, Oct. 5, 1922, p. 667.
[7] See *Automobile Engineer*, July 9, 1914, p. 223.

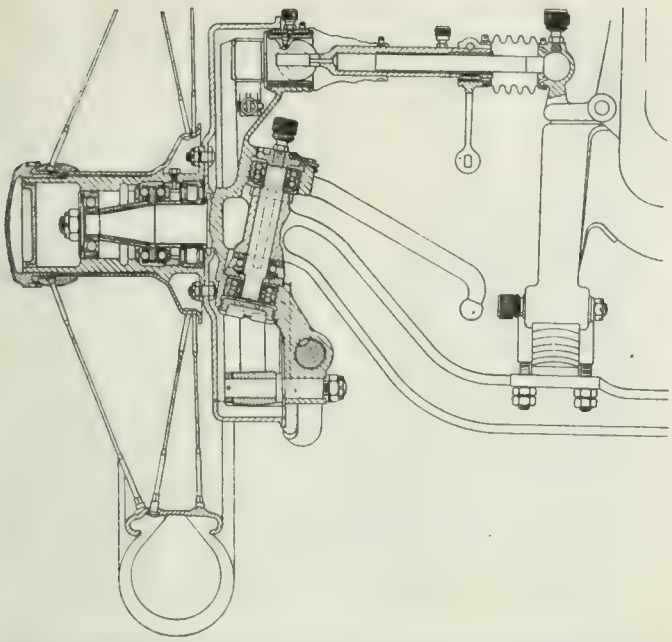


FIG. 12—ANOTHER EXAMPLE OF THE USE OF THE INCLINED PIVOT WITH THE FRONT-WHEEL BRAKE IS THE STEERING-MECHANISM OF THE DELAGE CAR

of the road to the next, castering action will give the car a tendency to follow a straight course; but it will not be the original straight course. . . . The tendency of castering action is not to preserve a straight course, but to restore the parallelism of the steering and driving wheels after the parallelism has been disturbed by whatever cause. It is, in fact, obvious that, since castering action must take place indifferently on either side of the center-line of the car, there can be no castering action while the car is proceeding in the direction of that center-line[8]. To my mind, the ideal form of steering-gear for a car intended principally for use on rough roads is the original Renouf type, the steering-pivots being vertical and in the planes of the wheels. This type has no castering tendency at any steering angle.

On a smooth and level road, castering action may be relied on.

While, on the level, by means of a judicious arrangement of steering details, combined with a skilful manipulation of speed in relation to curvature, a car may become self-steering so far as leaving a curve is concerned, it cannot automatically enter a curve from the straight.

The castering angle, or the fore-and-aft angle that the axis of the knuckle-pivot makes with the vertical, is usually from 1 to 3 deg., but angles as high as 6 deg. are employed. One experimenter, A. W. Werner, in a brief article entitled Steering-System Faults Explained,[9] states that angles of 4 deg. or more have resulted in violent wheel-wabble. He recommends making the caster angle equal to the angle of tilt of the wheel spindle, and states that 1¾ deg. is about the right value for both.

The castering angle is usually set by placing wedges between the spring and the spring-seat. It should be remembered that the castering angle sometimes varies with the deflection of either or both front and rear springs. The condition of average load should therefore be borne in mind in selecting the angle at which the pivot is set. One writer, in an article on Quarter-Elliptic

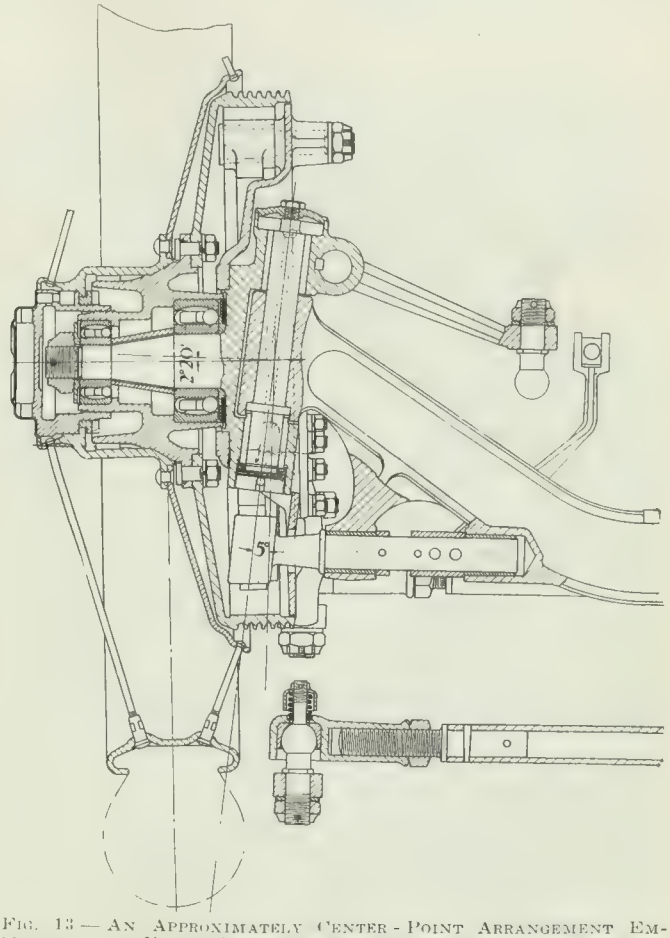


FIG. 13—AN APPROXIMATELY CENTER-POINT ARRANGEMENT EMPLOYED WITH FRONT-WHEEL BRAKES IN THE EXCELSIOR STEERING-KNUCKLE

[8] This means, apparently, no castering effect other than that due to gravity.

[9] See *Automotive Industries*, Dec. 7, 1922, p. 1139.

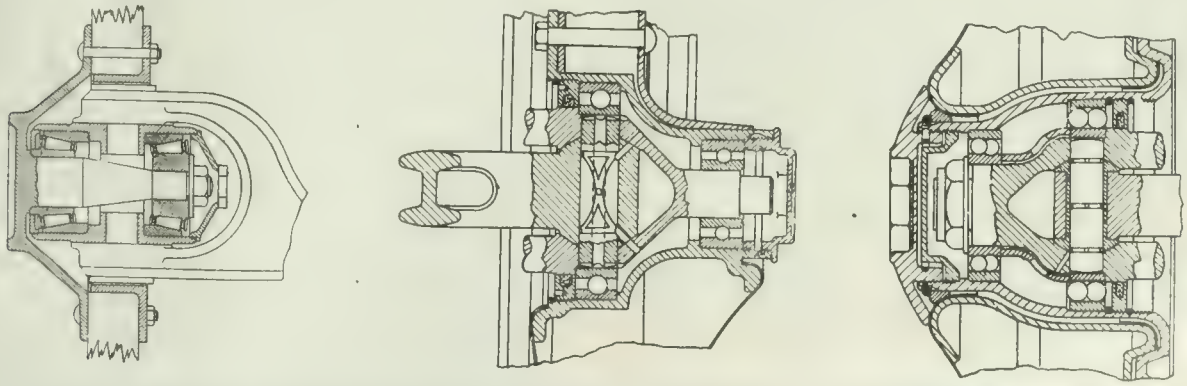


FIG. 14—EXAMPLES OF STEERING-KNUCKLE WITH THE AXIS IN THE CENTRAL PLANE OF THE STEERING-WHEEL
The Design at the Left Was Formerly Used on the Marmon Car, While the Other Two Were Suggested by J. P. Moore

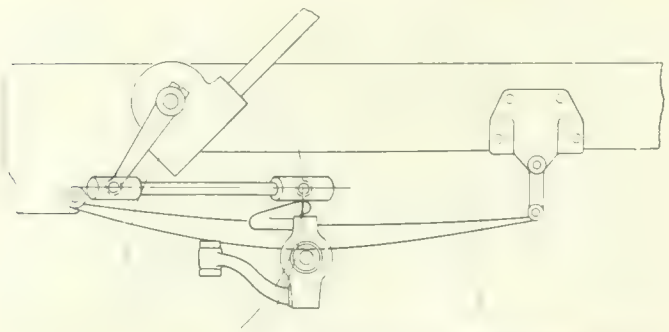


Fig. [illegible] The Drag-Link Arrangement Incorporated in the Mack Truck Chassis

Springs,[10] states that with quarter-elliptic springs the pivots tend to tilt forward in rounding a curve, thus giving an anti-castering effect. Items of this kind sometimes have a marked effect upon the steering of the vehicle, and therefore should be given close study in laying-down the design.

Wheel-Wabble

Among the common faults of the steering-system, and one whose causes are least understood, is that of wheel-wabble. This means the periodic oscillation in angular position of the wheel and axle spindle about the knuckle-pivot which results in the wheel following a course that deviates alternately to the right and the left of a straight line. When this phenomenon occurs, as it often does, in step with the natural period of the springs and front end of the chassis, the latter is given a violent transverse motion or shake popularly termed "shimmying."

If the front wheels of a vehicle be in equilibrium with respect to the knuckle-pivot in all angular positions of their spindles when the vehicle is in motion, wabble will seldom occur provided the layout of the drag-link and the spring is correct. But when the knuckle-pivots are inclined in either a transverse or a longitudinal plane, the wheels are in equilibrium in only one position and, if deflected from that position, they tend to swing back to and past it, oscillating in pendulum fashion unless the motion is damped-out by friction. Consequently, any chassis in which the knuckle-pivot is tilted has at least an incipient tendency to wheel-wabble.

Another primary cause of wheel-wabble is faulty layout of the drag-link in reference to the spring. If the drag-link is of rigid construction, or substantially so, and if the steering-gear arm is held rigidly, the end of the link attached to the knuckle-arm will swing through an arc when the front springs are deflected from their normal position. The axle-center is constrained, under the same condition, to move in a path that approximates an arc having as its center the eye in the unshackled end of the spring. These arcs seldom coincide exactly; consequently, the ball on the knuckle-arm is given some motion in respect to the axle center and, since it is constrained to move about the knuckle-axis, it causes the knuckle, the wheel spindle and the wheel to oscillate through a small arc, and the wheel wabbles. This is seemingly a self-evident fact, yet it is frequently overlooked or else the compromise chosen leaves much to be desired; for severe wheel-wabble is often caused by failure to consider this detail adequately. Cases have been known in which trucks have even suffered from broken frames or continually loosening engines and other parts due to a faulty layout in this regard.

Wheels or tires that are out-of-true or out-of-balance will also cause wobble. The three primary causes of wabble thus appear to be

(1) Unstable equilibrium of wheels carried on knuckles with inclined pivots
(2) Faulty layout of drag-links in reference to springs
(3) Lack of balance or failure of a wheel to run true

In addition, a considerable number of factors add to or help set-up wheel-wabble or render it more severe when once it is started. I shall not attempt to deal with all of these in detail, but will mention some that have been brought to my notice.

Friction tends to damp-out wabble, just as it does any other mechanical oscillation. Conversely, when it occurs, wabble is certain to be more pronounced when friction is at a minimum. This is why vehicles with loose or very free steering-connections are more apt to be addicted to wabble than those with joints set-up tight. Thus, wabble often can be stopped by tightening all steering connections, although it is a rough sort of remedy which, if not used with discretion, can result in excessive friction and rapid wear of parts.

The greater friction caused by under-inflated tires or increased weight on the wheels can easily damp-out wabble, and such items as anti-friction bearings on knuckle-pivots, better lubrication, loose-treaded tires and the like sometimes make wabble worse. This should not, however, be used as an argument against minimized friction in the steering-system, for it certainly is possible to have free steering without wabble if the system be well laid out and well constructed.

It is conceivable that wabble so slight as to be imperceptible to the operator can occur, especially if the steering-gear approximates the so-called irreversible type. It is clear also that any slackness or insufficient stiffness in any part of the steering-system or its supports, springs and spring parts included, which permits the wabble to take place through a greater amplitude than it otherwise would do, is apt to make the wabble more violent. Thus, a weak axle, frame or steering-gear housing, or insecure fastening of these members, will sometimes permit wabble that otherwise would not become evident. Much the same can be said of drag-links, tie-rods, tie-rod and knuckle-arms and steering-gear parts that are not stiff. Similarly, front springs that are weak or loosely fastened can help to amplify wabble; and weak springs in the drag-link will do likewise, as will also a whipping action of either drag-link or tie-rod. From the foregoing it will, I believe, be easy to see how wheel-wabble occurs.

It is not so easy to explain why violent shaking of the whole front end of the vehicle, which involves very heavy forces, sometimes results. To help clear up this point, let us consider the following. Suppose the wheel is wabbling, due to any of the causes enumerated, and is about to complete one deviation, say to the right. Suppose also that each time it reaches this position it strikes a road inequality that tends to accelerate its angular motion in the same direction; that is, an impulse in step with its natural period. It will swing still farther to the right, fetch-up short and be snapped back to the left, perhaps

[10] [illegible] May 1921, p. 162

Fig. 16.—The Dort Passenger Car Uses This Layout of Drag-Links

again receiving a blow from the road which accelerates it in that direction. Again it fetches-up and is again snapped back, building up a cumulative effect that can even become so violent as to put the car out of control. It is possible also that a physiological reaction from the arms of the driver can act as the force which accentuates wobble under some conditions. In any case, it happens sometimes that a car which is shimmying badly will cease to do so immediately if the driver releases his grip upon the steering-wheel. The freer the swing is and the greater the play in the linkage, the less damping-out there is and the more violent the shocks imposed in fetching-up in extreme positions will be. The front end of the frame, the engine, radiator and the like of course tend to follow the right-and-left oscillation of the wheels and, if the period is in tune with the natural period of the mass involved, the shake becomes exceedingly violent.

There are doubtless some gyroscopic forces involved in this wabble phenomenon. In this connection one commentator states that up-and-down motion of the spindle tends to induce a wabble of the wheel about an axis at right angles to the spindle. Another points out that a revolving wheel tends to resist deflection from its plane

Fig. 17—This Arrangement of Drag-Links Forms a Part of the Dorris Passenger-Car Chassis

of rotation; but that, once such deflection is started, only a small force will keep it oscillating. The amplitude of wheel-wabble that is caused by the lack of a perfect tie-rod and spring layout depends in part, at least, upon the length of the lever-arms involved. It is desirable to have the knuckle-arm connected to the drag-link as long as possible and still clear the spring, provided, of course, that it is made sufficiently stiff; for, the longer this arm is, the less will a given motion of its ball-end affect the course of the wheel. A long drag-link also has the advantage of swinging in an arc of less curvature than that of a short link.

Drag-Link Location

It is customary for steering-gear makers to advise their customers to locate the gear so that the ball on the gear-arm, that on the knuckle-arm and the pin on the unshackled end of the spring are in the same plane, or in line as viewed in side elevation, when the vehicle is under normal load. This brings the drag-link approximately in line with the main leaf of the spring. Others contend that a somewhat different layout is better. It is agreed, however, that the best layout is that which causes the least motion of the wheel spindle about the knuckle-pivot when the axle is moved under the influence of spring action. At best, the layout is a compromise which requires careful study if ill effects are to be minimized. A number of layouts employed on modern passenger-car and truck chassis are shown in Figs. 15 to 19.

There are some advocates of a transverse as opposed to a fore-and-aft arrangement of the drag-link. One of these contends that it avoids the use of a crooked drag-link and, in most cases, gives a better layout, especially when maximum wheel-cramp angles are considered. Another engineer takes the view that a cross-type drag-link is not satisfactory with the usual spring-suspension, a

Fig. 18—The Drag-Link Layout Incorporated in the Chassis of the Jordan Passenger Car

contention that he says is readily borne out by studying the layout on the drafting board. This may well be true in some instances, but it is evident that each case must be considered on its merits and the best compromises selected.

On some short-wheelbase passenger-cars and on trucks in which the driver's seat is well forward, a transverse drag-link arrangement is often satisfactory. The frame must, however, be designed to withstand the twisting stresses that such a layout will sometimes impose.

Irreversibility

There is much loose talk concerning the so-called irreversible steering-gear but, so far as I am aware, there is no such thing used as a completely irreversible steering-gear, nor does it seem desirable to employ such a construction, even though it should prove feasible to produce it. Perhaps the closest approach to an irreversible gear are the worm-and-wormwheel, or the worm-and-segment types. With these types the steering-wheel can be moved by applying a steady side-pressure on the road wheels, proving that gears of this type are not irreversible; but a sudden shock tending to deflect the road wheels from a given position has a tendency to cause such a gear to become momentarily irreversible or self-locking. This probably is due to the fact that the lubricant is momentarily forced from between the relatively small contact surfaces of worm and wheel, or segment, thus increasing friction and preventing the turning that would occur otherwise. On this account gears of these types are practically irreversible under shock, which is precisely the condition under which irreversibility is held by some to be desirable.

So far as I am aware, all other types of gears are reversible more readily than the worm-and-wheel and the worm-and-segment types and are therefore, for the same reduction-ratio and steering-system layout, more apt to permit any shock tending to deflect the road wheels to be transmitted to the steering-wheel. So, engineers take the view that it is not desirable to have the steering-gear approach closely the self-locking condition because, when so made, the linkage and bearings between the steering-gear and the wheels are stressed more heavily when shocks are imposed.

When the gear is free enough to transmit the motion caused by the shock to the steering-wheel, some of the

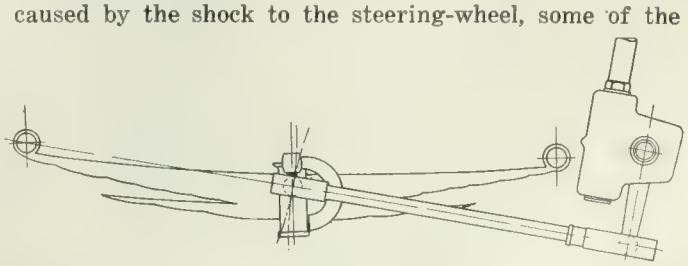


Fig. 19—The Buses in the Service of the Fifth Avenue Coach Co. Use This Arrangement of Drag-Links

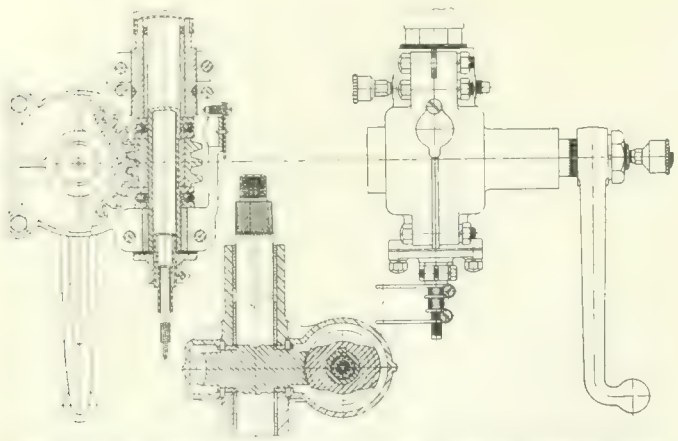


FIG. 20—THE GEMMER WORM-AND-WHEEL TYPE OF STEERING-GEAR

energy of the shock is dissipated in the mechanism of the gear, thus bringing about a certain cushioning action which is advantageous. If, however, the motion on the steering-wheel becomes excessive, it is much less comfortably handled by the operator. Those who favor the comparatively easily reversed type of gear are apt to favor also a center-point steering-arrangement which, as pointed out elsewhere, tends to eliminate shocks in the plane of the wheel, the kind of shock most frequently encountered. All things considered, it is probable that a certain degree of reversibility is a desirable thing, but clearly it is not desirable to employ gears that are so easily reversible as are those used in some present-day cars.

COMPARISON OF STEERING-GEAR TYPES

The following types of steering-gear are in more or less general use today:

(1) Worm-and-wheel and worm-and-segment
(2) Screw-and-nut, including differential-nut types
(3) Bevel-gear
(4) Planetary-gear
(5) Spur-gear-and-rack
(6) Cam

It is impossible to consider here all of the advantages and disadvantages of the various types, especially since it is not always easy to differentiate between advantages inherent in a type and those that are dependent chiefly upon a particular embodiment of it. When well proportioned and well lubricated, the worm-and-wheel type has excellent wearing qualities, even though the bearing area between the worm and the wheel is rather small. If, however, lubrication fails, considerable friction and rapid wear are apt to result. A disadvantage of this type is that it is practically impossible to take up any lost-motion caused by wear although, when the full wheel instead of a sector is employed, the wheel can be moved successively to four different positions 90 deg. apart, thus compensating for wear in the wheel but not for wear in the worm. It can be said, however, that well proportioned and well made gears of this type wear almost indefinitely, provided they are kept well lubricated; so, the disad-

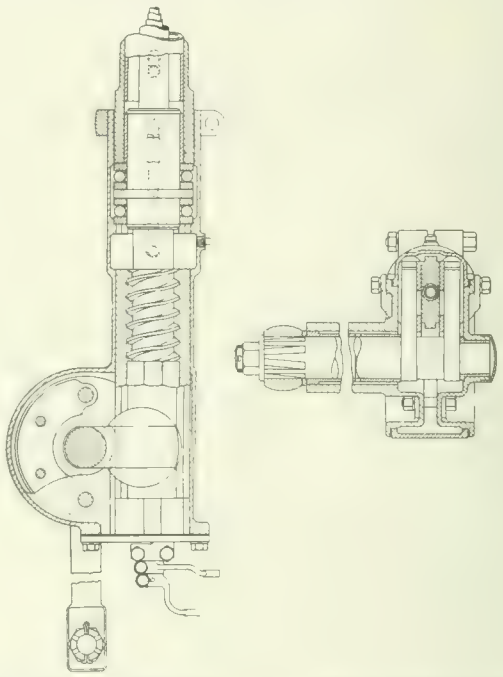


FIG. 21—THE ROSS SCREW AND NUT TYPE OF STEERING-GEAR USED BY THE AUTOCAR CO.

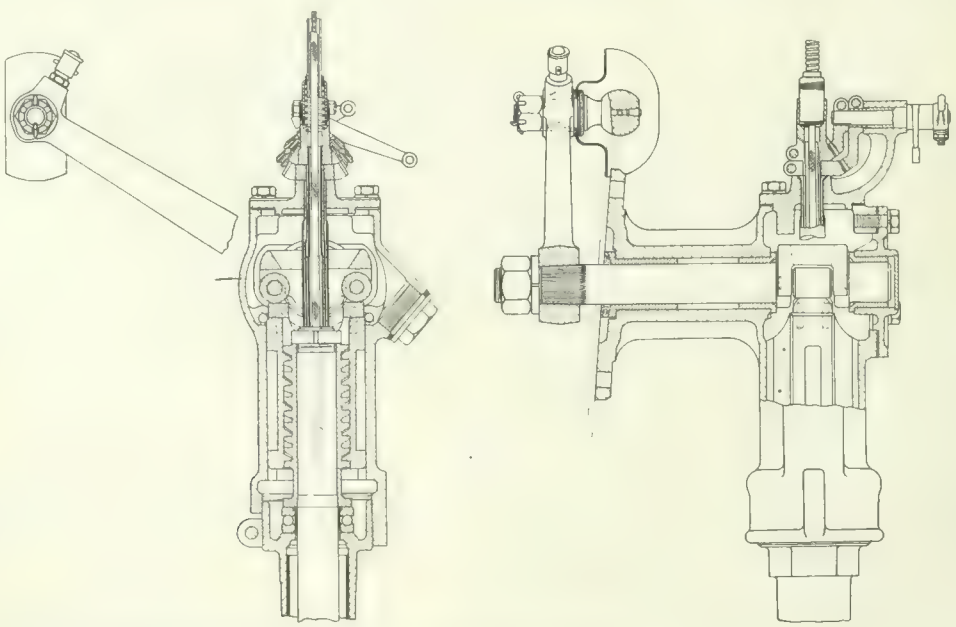


FIG. 22—THE PACKARD DIFFERENTIAL OR SCREW AND SPLIT-NUT TYPE OF STEERING-GEAR

vantage cited can be made relatively unimportant. Examples of the worm-and-wheel type of gear are shown in Figs, 5, 6 and 20.

One of the most widely used types of steering-gear is the screw-and-nut type, which is generally regarded as being very satisfactory when well made. A good example of this type is the Ross gear, in the form used by Autocar, shown in Fig. 21. The chief advantage of this type is good wearing quality due to the large bearing surface between the screw and the nut, and its chief disadvantages are its lack of adjustability and rather high cost of manufacture when the nut is well fitted to the worm. It can be said, however, that adjustment is seldom required provided, again, that lubrication is cared for properly. Alternative constructions of the same general type are used to overcome the disadvantage of non-adjustability just cited. In one of these the nut is made in two halves, one having a right and the other a left-hand thread, so that they move in opposite directions. This differential movement is transmitted to the steering-lever shaft by a mechanism that can be adjusted easily to take-up all lost motion. An example of this type of construction is the Packard gear shown in Fig. 22. In another make, the right-and-left threads are cut on the inner and outer surfaces of a sleeve, and the nuts or outer and inner mating parts are arranged to transmit their motion to a shaft on which the steering-arm is carried

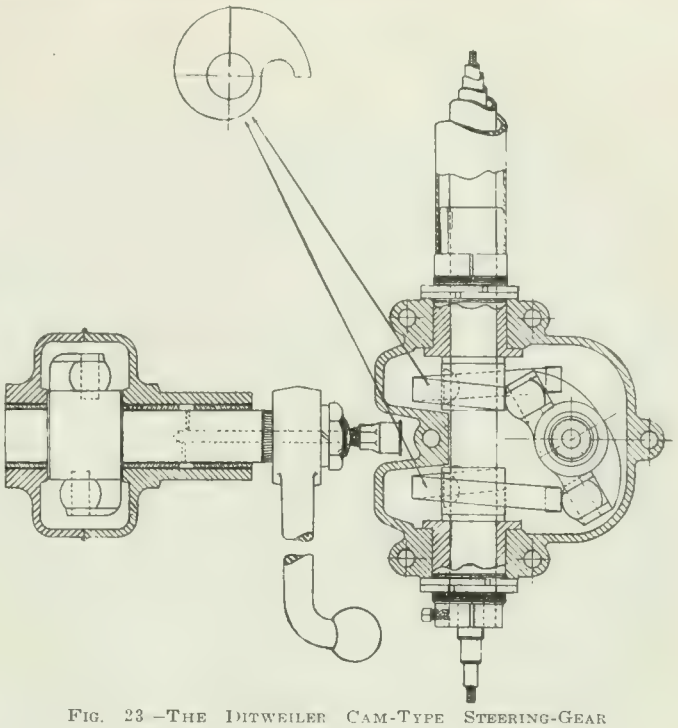


FIG. 23.—THE DITWEILER CAM-TYPE STEERING-GEAR

TABLE 1—DETAILS OF DIFFERENT TYPES OF STEERING-GEAR

Steering-Gear Details	NAME OF CHASSIS														
	PASSENGER CARS									TRUCKS					BUS
	Crane, Experimental	Dort, Model 25	Durant, Four	Franklin	Jordan	Marmon Model 34	Oakland, 6-44	Packard, Single-Six	Rolls-Royce 40-50	Autocar			Mack, 5-Ton	Service, 52	Fifth Avenue Coach Co.
Approximate Weight on Front Wheels, lb.	2,700	1,300		1,320	1,450	1,550	500	1,550	2,000	3,500	4,500	5,500	6,280	3,525	6,590
Transverse Rake of Knuckle, deg.	0	1	0	0		0	0	0	5	0	0	0	2	1½	0
Lateral Rake of Knuckle, deg.	1 to 2	½ to 1	3 to 5	6	4¼	4	6	3	1	2	2	2	2½	4	0
Type of Knuckle-Pivot Bearing	Roller and Plain	Phosphor Bronze	Bronze	Steel	Plain	Plain and Ball	Bronze	Plain	Plain	Roller and Plain	Roller and Plain	Roller and Plain	Plain	Roller and Plain	Bronze
Inside Diameter of Knuckle-Pivot Bearing, in.		¾″	¾″	1⅛	¾″	1½	1	¾″	1	1⅛	1	1⅜	1¾	1⅛	1⅜
Toe-In of Wheels, in.	¼ to ⅜	⅜	⅜ to 7/16	¼	¼ to ⅜	5/16	3/16 to ⅜	¼	½	⅜	⅜	⅜	⅜	⅜ to ½	0
Type of Steering-Gear	Worm and Wheel	Screw and Nut	Worm and Wheel	Worm and Wheel	Worm and Wheel	Screw and Nut	Screw and Nut	Worm and Wheel	Screw and Nut	Screw and Nut	Screw and Nut	Screw and Nut	Worm and Wheel	Screw and Nut	Screw and Nut
Reduction in Steering-Gear	29 to 3	7.50 to 1	7.50 to 1	6 to 1	7.50 to 1	9.50 to 1	7.80 to 1	9.45 to 1	9 to 1	8	12	15	12 to 1	12 to 1	10 to 1
Outside Diameter of Steering-Wheel, in.	18	16¾	16	18	17	18	17	17	17	18	18	20	20	20	18
Number of Wheel-Turns from Locked to Locked Position	1½(a)	1⅞	1¾	1½	2¼	1 23/64	1⅝	1 7/10	1⅝	1⅓	2	2½	1¾	1¼	1½
Length of Steering-Arm, Center to Center, in.	10½	8 1/16	5	5⅝	8	8 5/16	8½	8	9	6¾	8	9	9	7⅜	9
Maximum Angular Motion of Knuckle-Arm, deg.	45(a)	71	83	78	60½	67¼	80	65½	65	67½	70	73	61	38	59
Length of Drag-Link, Center to Center of Balls, in.	40	32	30⅝	23¼	23 11/16	33 3/16	15½	29	46	35¾	30¾	31	16	21¾	45
Distance from Spring-Horn Pivot to Center of Ball on Knuckle-Arm, in.	20	18½	(c)	18¼	16	17	15½	19¼	22	(c)	(c)	(c)	22⅛	19½	23 3/16
Approximate Maximum Motion of Front Spring, in.	6 to 7(b)	1½	4 to 5	6	4	2¾	4	6	6	4	4½	4¾	2 3/16		2
Maximum Angular Motion of Steering-Gear Arm, deg		70	84	90	92½	71	75	65½	52	60	60	60	65	37	54
Length of Steering-Knuckle Arm, in.	8	6⅝	5⅛	7⅝	6½	8 5/16	8	8	7¼					6½	8 3/16

(a) Approximate (b) No load to bottom. (c) Transverse drag-link.

by the use of a mechanism much the same as that shown in Fig. 22.

Types (3), (4) and (5) are used by only a few manufacturers, chiefly on light cars where a large reduction is not required and where easy reversibility is not considered of much importance, or is outweighed by a relatively low cost of production. The latter is about the only advantage of these types, unless their ability to operate after a fashion without, or with indifferent, lubrication is regarded as an advantage. It is worthy of note, however, that some recent designs of American passenger cars intended for large production at a low price are equipped with the worm-and-wheel type of gear, so that any advantage that types (3), (4) and (5) may have in respect to low production-cost appears to be outweighed by their inherent disadvantages.

The only example of the cam type with which I am familiar is produced under Marles patents. The Ditweiler gear illustrated in Fig. 23 is of this type. It has yet to see any very wide commercial application, but it has the advantage of simplicity and is said to have high mechanical efficiency. This type of gear has been designed to give its full motion with either one or two complete revolutions of the steering-wheel.

There is considerable difference of opinion as to the total reduction that is necessary or desirable in the steering-gear. This reduction naturally depends to a great extent upon the weight of the car and the mechanical efficiency of the mechanism employed. The reduction ordinarily used on passenger cars varies from 6.0 to 1 to 9.66 to 1, and the number of revolutions of the wheel necessary to move the road wheels from locked to locked position varies from 1.5 to 2.25.

There are certain advocates of rather "fast" steering-mechanisms; that is, mechanisms which require a relatively small angular motion of the steering-wheel for a given angular motion of the road wheels. Others prefer a "slower" gear, or one with a greater reduction, even though this type does not respond so rapidly to the demands of the operator. Other things being equal, the slower the steering is the less are shocks on the road wheels transmitted to the steering-wheel, and vice versa.

Tie-Rod Arms and Tie-Rods

Tie-rod arms should be as stiff as weight and manufacturing considerations admit. If yoked tie-rod ends are to be employed, it is important to see that the axes of the holes in the yoke pins are truly parallel to each other and to the knuckle-pin axes; otherwise, if the yoke pin is well fitted, binding will occur in some positions. If the knuckle-pivot axes are not intended to be parallel, as in the case of transversely raked pivots, it is necessary to use a ball-joint or its equivalent between the ends of the tie-rod and the tie-rod arms to prevent binding in the mechanism.

One prominent designer states that it is practically impossible to fit yoked tie-rod pins tight enough to prevent rattle and still avoid binding. Even though the knuckle-pivot and yoke-pin axes be made truly parallel in machining, they are certain to be thrown somewhat out of this relative position when the axle is deflected, as it always is to some extent under normal load. For this and other reasons a ball-and-socket joint such as is used on the ends of the drag-link has important advantages. Some engineers consider it safer than the ordinary yoke construction. The springs back of the bearing-blocks afford a certain cushioning action against shock which, if the springs are proportioned properly, is highly desirable. An unusual design of ball-and-socket tie-rod end is used in the Excelsior design as will be seen from an examination of Fig. 13.

A rather common and serious fault of some of the cheaper cars and trucks is the use of tie-rod yokes that are fitted poorly to begin with, and that have a totally inadequate means for locking them in position. The tangent bolt employed is frequently too small, and the shank of the yoke is not split far enough or with a wide enough slot to insure secure locking. As a result, the yoke soon rattles loose and becomes a source of danger. When the tie-rod is of tubular section, and especially when the walls of the tube are thin, care must be used to see that sufficient metal remains at the base of the thread to prevent failure under constant vibration. A yoke clamped to the tube by a tangent bolt sometimes compresses the tube under the influence of road shocks, and the yoke loosens on this account. This fault has been remedied in some cases by the use of a tight-fitting metal-plug, somewhat longer than the threaded portion, forced into the ends of the tube. There are some advantages in the use of a lock-nut against the inner end of the yoke-shank instead of a tangent bolt, but close-fitting threads are very important in this case.

Data on steering-gear details employed on different types of chassis are presented in Table 1.

THE DISCUSSION

Cornelius T. Myers:—Of the multifarious compromises that must be effected in automobile chassis design, those that affect the steering mechanisms are of great importance and worthy of much careful study. Many an otherwise clean piece of automobile architecture can be more or less severely criticized when the steering layout is carefully analyzed. These mechanisms constitute a really large problem in chassis design, because they must not interfere with the many others in front of and just behind the dash; they must be easily assembled and dismantled, they should afford the maximum of access to and for dismantling adjacent parts and, most important of all, they must afford safe and sure control of the direction of the car at all times.

In respect to safety, effective brakes rank first in importance and steering mechanisms a close second.

A recent editorial in *Automotive Industries* referring to the violent wabbling of the front wheels under certain conditions, has turned the spotlight on steering mechanisms by asking the question, "what makes 'em shimmy?" What this expression lacks in dignity it gains in pertinence; and it is gratifying to note that there is no lack of opinion among the engineers of the industry as to the cause and its cure, which should be readily effected.

Having listened to and read with great interest the views of several well qualified to speak on the subject, I offer to the discussion two or three explanations not heretofore advanced, and which it is hoped will be of some service.

First: A feature of major importance in the layout of a steering mechanism is the relation of the path of travel of the *ball* on the steering-knuckle arm when under the influence of spring vibration, to the position of the ball on the arm of the steering gear itself.

Figs. 24 and 25 are typical layouts showing two lines of travel for the steering-knuckle ball, and the axle itself as the springs deflect. The axles, with their knuckle-pivots, follow the lines *xx* due to the flexure of the springs. The balls on the steering-knuckle arm in each case follow approximately the arcs *yy* that have for centers the centers of the balls on the steering-gear arms.

It is seldom that these two arcs coincide for any appreciable distance, and in some cases, as in Fig. 24, they diverge considerably as the axle is raised or lowered with respect to the frame when the springs flex. In looking at the Figs. 24 and 25 note that the arc xx in each case is the path of the center of the ball on the steering-knuckle arm provided the steering-knuckle is held so that it cannot turn about its pivot, and provided the ball is not connected to the steering-gear arm by the drag-link.

But actually the ball cannot follow this path because it is connected by the drag-link to the ball on the steering-gear arm. It must swing, in a vertical plane, through an arc centering about the ball s on the pitman arm of the steering gear, and also in a horizontal arc about the center of the steering pivot on the axle.

Referring now to a plan view, Fig. 26, p and q are the steering pivots held by the ends of the axle, b is the ball

FIG. 24—DIAGRAM OF TWO STEERING-SYSTEMS SHOWING THE RELATIVE POSITIONS OF THE SPRING AND THE DRAG-LINK AND THE STEERING-ARM

on the steering-knuckle arm of the axle and is connected by the drag-link to the ball s on the steering-gear arm and c and d are the clevis pivots at the ends of the tie-rod.

Assume that the left wheel, striking a bump, rises. The point p on the axle, traveling along the arc xx in the left portion of Fig. 24, reaches the point p_1, Fig. 26. The ball b on the steering-knuckle arm moves along the arc yy, in the left portion of Fig. 24, and reaches b_1, Fig. 26. Thus the wheel spindle which was normally in the position pm, now takes the position p_1m_1, and the clevis c moving to c_1 changes the position of the right wheel spindle from qn to q_1n_1. Thus with the steering layouts, as in Fig. 24 and the right half of Fig. 25, any rise of the left wheel will tend to turn the car to the left and a fall of the left wheel will tend to turn the car to the right. With a layout as in the left half of Fig. 25 this action will be modified and much diminished, the car tending to turn to the right whether the left wheel rises or falls.

Under certain road and speed conditions this action will cause the wabbling and resultant "shimmying" to which reference has been made. Some cars have a greater tendency to wabble than others, due largely, as will readily be seen, to the varying rates at which the paths xx and yy diverge in any particular steering layout.

Second: The other feature bears on the first one, just demonstrated, and in my experience it accounts for the astounding violence of this wabbling at times. Wabbling seems to be the greatest when there is a very perceptible amount of wear in the steering-pivot bushings, wheel bearings and other points of wear or possible looseness. When successive bumps or depressions in the road surface synchronize with the taking up and giving out of the total amount of wear or slack, the wabbling seems to be most severe. It is somewhat analogous to snapping a whip, or more directly to a chain in which the links are long in proportion to their width. The end links suddenly reverse their direction of motion when the chain is snapped like a whip, for they receive a violent check when, having attained some velocity, the slack suddenly reaches its limit and the reaction causes a partial reversal. If the grasped end of the chain is reversed at the right moment the free end can be kept swinging from side to side in a regular period of vibration. The

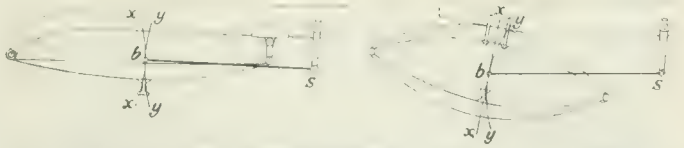


FIG. 25—TWO OTHER STEERING-SYSTEMS HAVING VERY DIFFERENT ARRANGEMENTS OF THE SPRING AND THE DRAG-LINK AND THE STEERING-ARM

stresses in the chain will be greatly increased if a weight is attached to the free end, and the analogy of the return ball on a rubber cord is also apparent.

In an automobile the links of the chain are the various parts and their connections, namely: Wheel-hub bearing races, axle spindles, steering pivots and their bushings, the various pins and links in the steering mechanism, the spring bolts and their bushings. The ball on the end of the "chain" is the front end of the frame with engine, radiator, etc.; or the engine itself, if it is at all loose on its fastenings. When a series of road bumps synchronizes with the vibration period of the springs, and this period is some harmonic of the whipping "chain" of loosely connected parts, "she shimmies," and sometimes with a vengeance.

Third: A point on which I am still experimenting, is the influence of the unbalanced forces set up in the front wheels by the weight of the tire valves and adjacent parts. Due to the fact that the wheel spindles are not horizontal, these unbalanced weights move from and toward the chassis as the wheels revolve.

It would appear that when the position of the valve in the left wheel bears a certain relation to the position of the valve in the right wheel, the forces set up as these valves revolve will counteract and tend to balance out. On the other hand, the relative location of the two valves might be such that the two forces were additive.

If there is looseness in the steering pivots and connections, and the speed of rotation of the wheels is such that these forces act in harmony with the "whipping chain" mentioned above, it seems altogether possible that they can either produce and intensify wabbling or intensify it when produced by some slight road inequality. I have known bad cases of wabbling to start on comparatively smooth concrete roads when the car was driven in one direction, but no wabbling occurred when driving over the same stretch in the opposite direction at the same

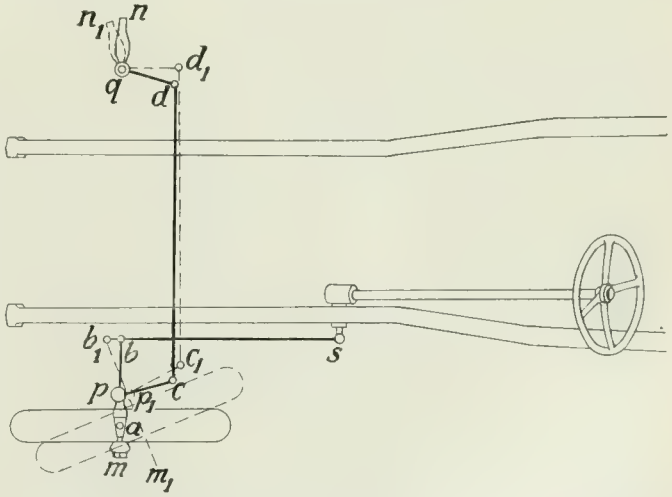


FIG. 26—DIAGRAM SHOWING THE RELATIVE POSITION ASSUMED BY THE PARTS OF THE STEERING-SYSTEM WHEN THE WHEELS ARE IN THE STRAIGHT-AHEAD POSITION INDICATED BY THE FULL LINES AND WHEN TURNED AS INDICATED BY THE DOTTED LINES

speed. Turning the car around changed the relative position of the two-tire valves, and evidently caused a balancing out of forces that had previously promoted and aggravated the condition.

The conditions under which the violent wabbling takes place depend upon a number of different factors; (*a*) the steering layout, (*b*) the inequalities of the road, (*c*) the vibration period of the springs, (*d*) the speed of the car, (*e*) the weight of the front end of the car, (*f*) its moment of inertia about a vertical axis, (*g*) the tire inflation, and (*h*) wear and looseness of front axle and steering-gear parts, etc. It is not easy to simulate these conditions, and often minor changes of one kind or another seem to cure the trouble; but it is latent if the steering mechanism is not correctly laid out, and will reappear under somewhat different conditions than at first.

In driving a car which has a recurrent tendency to wabble badly, I have found that turning steadily and not too sharply to one side or the other will check the phenomena if it is not allowed to become too violent. As a rule it is best to drive on the right side of a crowned road so that one must continually exert a little left-arm pull on the steering-wheel to keep a straight course. This takes the slack out of loose steering connections, and obviates any wabbling due to looseness only. A further turning toward the left or crown of the road will take up any slack produced when wabbling is started by impressed vibration from road bumps, and will often damp out the wabble before it becomes severe.

In *Automotive Industries* an article appeared entitled Wheel Wabble and Other Steering System Faults, by

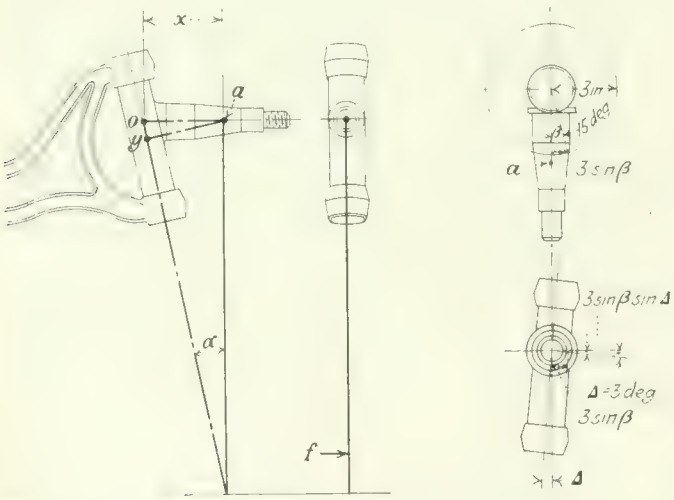


Fig. 27 Diagrams Illustrating the Effect of the Transversely Raked Steering-Pivot at the Left and at the Right the Small Amount of Spring Motion Occasioned by a Slight Rearward Rake of the Steering-Knuckle Pivot

A. Ludlow Clayden[11] who sets forth several points with reference to steering mechanism that can certainly be given close attention.

It is particularly gratifying to note his denial that a transversely raked steering pivot makes for easy steering, even when the extension of its axis touches the ground plane at the central point of tire contact. This practice is seldom used in the United States, and with good reason, but it has a number of foreign adherents who are loud in their claims for it.

In connection with transversely raked steering pivots, however, it is hard to believe that Mr. Clayden is correct when he states that front wheels are in unstable equilibrium when they are pointed straight forward; also when he states that with the drag-link disconnected the wheels would swing against the frame of the car either in one direction or the other. Referring to the drawing at the left of Fig. 27, the point *a* on the spindle, whether the wheel is turned in or out, moves in a circle the plane of which is perpendicular to the axis of the steering-spindle. Thus, no matter in which direction the car is turned, in the view shown, the point *a* moves along the line *ay* perpendicular to the axis of the steering pivot. This movement tends to lower the wheel and raises the car, so that the front wheels, uncontrolled by forces exerted through the steering mechanism, tend to point straight forward and become stabilized in that position, under the influence of the weight of the car. Cars with such a steering mechanism have a considerable tendency to be self-righting, but with any looseness in pivot bushings and steering connections, the wheels can set up a violent and persistent wabbling once the right conditions are encountered.

Mr. Clayden's theory, that the tendency to raise or lower the wheel when turning the car, due to a fore-and-aft raking of the steering pivots, is the primary cause of wabbling, is an interesting one and worthy of close study. That the use of vertical pivots will always cure the trouble is doubted, however, as wabbling has been noted in cases where the pivots were vertical.

There seems to be much more likelihood that the interaction of springs and steering leverages is the primary cause of the trouble, and that this is aggravated by loose connections. Mr. Clayden's statement that increased friction in the connections prevents wabble is in line with the view expressed in the second item in this discussion.

As to a comparison of effects on wheel wabble of rearwardly inclining the pivots as opposed to the spring action, Mr. Clayden states that, due to inclining pivots, one wheel may drop and the other rise perhaps ¼ in. in making a turn of minimum radius where the inner wheel is cut say 30 deg. from straight forward position. A 30-deg. swing does not occur in wabbling. Five degrees is about the average on either side of neutral position, unless there is a considerable looseness in the connections, and 15 deg. is perhaps a maximum, giving a total swing of 30 deg. from extreme to extreme.

Assume that the knuckle pivot is located in a vertical plane, according to the usual American practice, and not inclined transversely toward the frame. The average rearward inclination of the steering-knuckle pivot is less than 3 deg. = angle Δ. Taking the distance x in the drawing at the left of Fig. 27 as 3 in. we have the rise or fall of each wheel = 3 sin β sin Δ (See the drawing at the right of Fig. 27.) Where β = 15 deg. we have a movement = 3 x 0.250 x 0.052 = 0.039 in., which is only one-sixth of the ¼ in. mentioned by Mr. Clayden. This is hardly enough to account for the wabbling, as the corresponding force must be applied through a reduction of about 20 to 1, thus in moving up or down this 0.039 in. the point *a* has circled a distance of

$$(2\pi \times 3 \times 15) \div 360 = 0.7854 \text{ in.}$$

and

$$0.7854 \div 0.039 = 20.2$$

The point *a* in moving about ¾ in. bends to compress the spring about 0.04 in. If the stiffness of the spring is 400 lb. per in. the measure of the compression due to the movement of *a* is about 16 lb. If this is reimpressed by the spring on the steering-knuckle it cannot be more than

$$16(0.039/0.785) = 0.79 \text{ lb.}$$

[11] See *Automotive Industries*, Oct. 5, 1922, p. 667.

or less than 1 lb. at the point *a*. Even this will be considerably reduced because of the friction losses in the spring leaves, in the pivot bushings and thrust bearings.

While it may be true that even this feeble effort tends to impress a wabbling motion to the wheels, it would appear to be unlikely that it is the real cause of the trouble. On the other hand, even a small divergence in the arcs *xx* and *yy* develops forces which are applied by direct and powerful leverages, and can reach a considerable intensity under conditions of synchronous vibration. This has been confirmed, in my experience, by the fact that wabbling has never occurred when only the right-hand wheel was encountering a series of road waves that would sometimes cause the wabbling if the left wheel passed over them. As the cars were left-hand steer, bumps under the right-hand wheel had but little effect on the left-hand steering arm that was connected to the drag-link.

Placing the steering spindle in the middle plane of the wheel, as advocated by Mr. Clayden, will not obviate wabble if the steering layout is faulty, and such a design has some serious drawbacks.

To obviate wabble

(1) Steering mechanisms must be laid out so as to prevent an appreciable angular movement of the knuckle steering-arm when the spring flexes

(2) Steering pivots should be ample in size and the bushings spaced as widely as possible so as to minimize bearings loads

(3) Provision for continuous lubrication of pivot and tie-rod bushings must be provided so as to prevent wear.

PROF. E. P. WARNER:—There is some danger of our overemphasizing the effect that mechanical play may have in connection with wheel-wabble and the "shimmying" of the car. To indicate how bad a wabble we can get without any possibility of mechanical play, we can turn to a vehicle in which wabble does appear very badly although the steering-gear is rigid throughout; that is, to a motorcycle, a bicycle, or other hand-steered vehicle of a similar type. As some probably know from experience, on a motorcycle at high speed, even on a smooth road-surface, a terrific wabble sometimes arises. That is sometimes experienced also on bicycles that do not have a spring-fork. It is reported that one of the British "scooters" of recent design, a vehicle with a rigid steering-column and a platform on which the driver stands, wabbled so badly as to be absolutely out of control at all speeds above 12 m.p.h. In at least three cases of which I have seen reports recently, that tendency to wabble, which was terrifyingly bad in the original machine, was cured by changing the curvature of the fork, which, of course, is equivalent to changing the castering of the wheel.

Do the figures for the reduction-ratio in Table 1 of the paper relate to the reduction in the gear itself or to the total reduction from the steering-wheel to the road-wheel?

HERBERT CHASE:—The figures given in the table are the answers to a questionnaire on the "reduction in the steering-gear." I am not certain what was understood by this, but believe that in most cases the information given applies to the actual reduction in the gear alone.

M. C. HORINE:—Mr. Chase mentioned the use of anti-friction bearings as a means of reducing friction in the steering-system. Does he mean to include the steering-knuckle pins in that category? Does he find that the use of anti-friction bearings in king-bolts is a good thing? It seems to me that an anti-friction bearing is fundamentally something made to turn, having point or line contact. If placed on a very slowly and only occasionally oscillating member, such as a steering-knuckle pin, the tendency would be for the balls and rollers to embed themselves in their races and produce hard instead of easy steering. Is it not true that center-point steering would really make it more difficult to steer, particularly at low speeds or when the vehicle is stationary, due to the fact that it is harder to grind the wheel about on a point instead of rolling it about a point?

It has been a source of amazement to me for a number of years that mystery as to the formula for fore-gather seems to be prevalent only in the automotive industry. The rules for wheel-setting are rather well established and well known in the horse-vehicle industry. The setting of the ordinary horse-vehicle axle is governed by well defined laws. It might be well for the Research Department to investigate them.

Another point that may not have anything to do with wheel-wabble but certainly relates to steering-gears, is the very general practice on the part of automotive manufacturers of using a standard front-axle for several different wheelbases. That is particularly true in the truck industry, in which there is a considerable range of wheelbase options on a chassis using one standard axle. In the case of assembled trucks, an axle is built for a large number of vehicles having different wheelbases, the tie-rod arms being placed at a certain angle. That angle is not changed for the different wheelbases. If we study the Ackerman system, we find that the accuracy of steering, even as to the turning-radius and certainty as to the tire wear, is very largely affected by the angle of the steering-arms.

In connection with the proper layout of the steering-gear, one point that has been rather stressed is the position of the drag-link, assuming that to be of the fore-and-aft variety, to achieve the minimum divergence of arcs as between the motion of the front axle about the fixed point of the spring and the motion of the drag-link about the presumably fixed position of the steering-gear arm. Mr. Chase illustrates in Fig. 15 a type of mounting wherein the steering-gear is located in front of the axle instead of behind it. That is not exclusive to the make he mentions, but is used by three American companies and also by a number in England. Has Mr. Chase any data concerning it?

Concerning Mr. Myers' assertion that, in the matter of safety the brakes come first and the steering-gear second, would Mr. Myers prefer to find himself in traffic, in an emergency, with a broken drag-link or a broken brake-rod?

MR. MYERS:—With a broken drag-link the car will tend to go straight ahead and good brakes will stop it.

MR. HORINE:—The Curtis Co. solved the problem of motorcycle wheel-wabble 15 years ago. In ordinary construction the center-line of the pivot of the member on the top of the fork, that corresponds to the king-bolt on a wagon, does not intersect the axle of the wheel but comes somewhat behind it, crosses the vertical center-line of the wheel and intersects the road at a point in front of that of tire contact. The Curtis arrangement was to extend that center-line so that it intersected the axle, and to use perfectly straight forks, a construction for motorcycles that is almost universal practice on automobiles today.

O. A. MALYCHEVITCH:—Does Mr. Chase consider that an equal number of turns of the steering-wheel ought to be required to steer to the right and to the left; say to have two turns of the steering-wheel to steer to the

right and two turns to steer to the left? I have found that this is very seldom true on the chassis. In designing buses, the steering is a very important item. After experimenting and also from the literature[12] I observed that if the drag-link is parallel to the axis of the chassis as at the left of Fig. 28, the angle between the arm connected with the drag-link and that connected to the tie-rod ought to be equal to 90 deg. If the drag-link is inclined to the right or to the left, the angle ought to be correspondingly increased or decreased as shown in the central and right portions of the illustration.

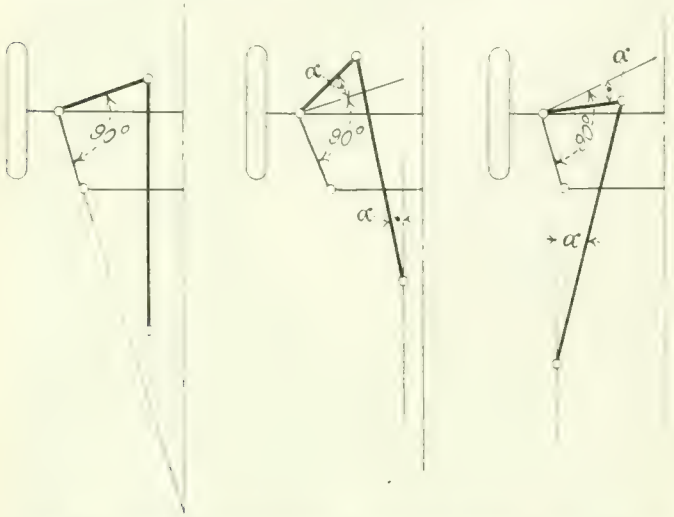


FIG. 28—DRAWING SHOWING THE RELATION BETWEEN THE PARALLELISM OF THE DRAG-LINK WITH RESPECT TO THE CHASSIS AND THE ANGLE BETWEEN THE ARMS CONNECTED TO THE DRAG-LINK AND THE TIE-ROD

Regarding irreversibility, one of the most efficient types of steering-gear is that found on the Schneider omnibus chassis used in Paris and described in *Engineering*.[13] In this form of steering-gear, which is of the screw-and-nut type, the steering shaft that is located near the steering-wheel has a ball-and-socket joint to allow a swinging motion of the screw and the nut on the other end of the shaft; the nut of the steering-gear being connected with the steering-lever. The whole arrangement is very simple and efficient and keeps the steering-system from irreversible action when the shocks come on it. It is said that it is a very quiet steering-system, with no wabbling or kick on the hands of the drivers in such traffic as that in Paris.

OTTO M. BURKHARDT:—Quoting Mr. Chase's statement, where he is referring to the center-point steering layout, we note,

> (1) Road shocks in the plane of the wheel have a minimum moment about the knuckle-axis and, consequently, are transmitted in a less degree to other parts of the steering mechanism

This statement is susceptible of some further qualifications that have come to my attention lately. With center-point steering, the moment of the forces acting on the wheel is of smaller magnitude but, in spite of this, small-magnitude forces in the case of center-point steering are more readily transmitted to the steering-wheel, unless the forces applied are equal on both wheels, which very rarely happens. If one wheel is subjected to a shock, it is not resisted by the other wheel in the same manner as in the conventional American type of steering. The greater the distance from the point of contact between the tire and the road to the axis of the king-pin, the more readily does the wheel act as a shock-absorber.

[12] See Etude de Direction, by P. Ravigneaux; published in *La Technique Automobile*, 1914 and 1920.
[13] See *Engineering*, April 14, 1916, p. 343.
[14] See THE JOURNAL, July, 1922, p. 91.

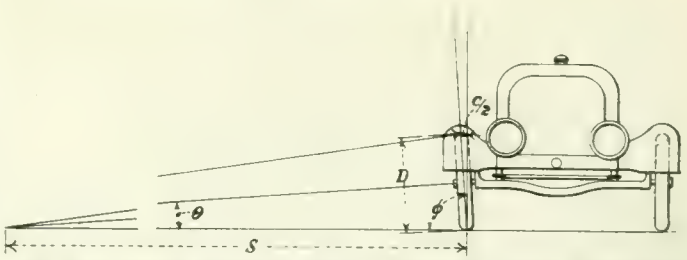


FIG. 29—DIAGRAM SHOWING HOW A CAMBERED WHEEL RESEMBLES THE BASE OF A CONE LYING ON ITS SIDE

With regard to determining the foregather, this is very carefully analyzed by J. C. Sproull.[14] Quoting from Mr. Sproull's paper and referring to Fig. 29, it may be considered that the wheel forms the base of a cone lying upon its side as shown. The natural path of such a wheel, when it rolls on a plane surface, is the circumference of a circle described about the apex of the cone as assembled. Obviously, unless the front wheels have gather, there will be a tendency for them to separate, when they roll on a plane surface.

From Fig. 29 we read the following equation:

$$\cos \Phi = \sin \Theta = C/2D$$

From the figure it is further evident that

$$\sin \Theta = D/2S$$

Hence

$$S = D/2 \sin \Theta$$

From Fig. 30 we observe that the area of the tire in contact with the ground is of the length L. The cone distance, as previously mentioned, is S. We read from Fig. 30

$$\sin \alpha = L/2S$$

The proper amount of foregather is obtained by making $pq = qr$. From the geometry of the figure it follows that

$$qr = (L/2) \tan \beta = S\,[(1/\cos \alpha) - 1]$$

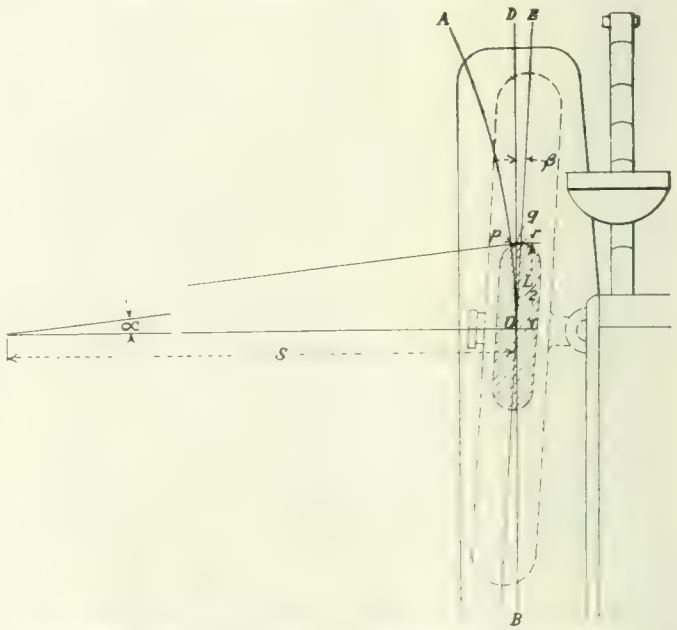


FIG. 30—DIAGRAM ILLUSTRATING THE RELATIONS THAT EXIST BETWEEN CAMBER AND GATHER

In the article mentioned, values have been substituted and tables worked out for practical values of the wheel diameter and the transverse inclination of the steering-pivot.

Mr. Myers mentioned that bearing loads are very important in steering. I agree that the loading of the king-pin bearings has considerable influence on the ease of steering. Figs. 1 and 3 of the paper illustrate three designs that perhaps are representative. Let us consider Fig. 1. We have there a steering-knuckle in which the steering-pivot is overhanging; that is, in case of side-sway, the upper bearing will have to resist a force that is the sum of the side-sway and its reaction, as we have it in the bevel pinions where we have an overhang. Fig. 3 represents a condition of bearings that are fairly symmetrically mounted, what we could call straddle-mounted. There the side-sway would only be one-half on each bearing.

I have not yet seen any clear emphasis in the literature as to what the bearing loads really are. The matter is at first somewhat deceiving. In the case of the Crane design, which is a late job, we find the bearing mounted directly in the knee of an angle. It seems that this bearing gets a tremendous load, but it does not.

A. J. SCAIFE:—Mr. Chase emphasized the desirability of using the ball-and-socket joint in the cross-steering rod-end. We used this construction several years ago but abandoned it because the ball did not retain its spherical shape; it became flattened or oval in shape. When the lost-motion is taken-up on the ball-and-socket joint, the steering becomes cramped when turning to the right or to the left; we therefore abandoned this construction and substituted that of the pin and yoke.

We have had considerable experience in the use of an anti-friction bearing on the top of steering-knuckles to carry the load. It is true that either the ball or the roller bearing will pit, but under the pitted condition these bearings have less friction and turn more easily than the large plain-bearing surfaces, as the friction in the steering-knuckle is in proportion to the bearing surfaces. A continuous ring in the ball race instead of balls has been tried recently with success. It reduces the friction and decreases the wear.

I had a case where the wheel-wabble was extreme. The steering mechanism was loose in every joint; in fact, the lost-motion of the steering-wheel was so great that you could turn the wheel about one-half revolution. Without tightening the joints or taking out the lost-motion, it was possible to eliminate the wabble of the front wheels by inserting a taper wedge between the spring-seat and the springs on the front axle, changing the angle of the caster. This proved to my mind that the caster has considerable to do with the wabble.

It is necessary that the drag-link be designed properly, with suitable relation to the front spring-eye and the steering-arm. We believe it is not possible to eliminate wheel-wabble by simply maintaining tight connections on the steering-gear.

L. H. POMEROY:—Many speakers have discussed the difficulties arising from the relative movement of the drag-link and the front spring. Why not shackle the front spring at its forward end so that the steering-arm will be subject to the influence of two links moving with sympathetic curvatures and not the reverse as is usually the case? This practice has been used by De Dion in France for years and by the Fifth Avenue Coach Co. and seems so obviously right as to make it difficult to understand why the practice is not universal.

Another matter worthy of far more attention than it usually gets is the point where the steering-arms produced intersect the longitudinal axis of the car. On the 1913 Vauxhall cars this point was located a distance about 56 per cent of the wheelbase, measured from the front axle toward the rear. While the steering was delightfully free, the experience at the Front with these cars was that when in deep mud the driver had to descend from his seat to find in which direction the wheels were locked. In a word the steering-gear itself had no powers of recovery or sense of direction. Lengthening the distance of the intersection of the steering-arms and the longitudinal axis from 56 to about 65 per cent made all the difference. While steering was not so free as before, the natural sense of direction was vastly improved.

Remarks have been made on the inadequacy of ball joints. Unfortunately these are essential with inclined pivots. The important thing seems to be that of keeping mud and water out of the joint. If this is done no trouble should arise; otherwise trouble will arise irrespective of whether ball or pin joints are used.

The subject seems to boil down to the fact that wheel-wabble can be caused by half a dozen different factors but needs the presence of three or more of them, thus giving about 20 distinct and accurate diagnoses. I remember a client who many years ago insisted upon heavy detachable rims as well as detachable wheels. During the very first run on the car when everything was tight wheel-wabble developed to such an extent that traffic was stopped to allow him to proceed. Investigation showed that releasing the steering-wheel when the wabble started restored matters to normal, the eventual complete cure being obtained by discarding the heavy rims.

A. D. T. LIBBY:—Mr. Chase has disavowed any originality in connection with his paper. It seems to me that he should have listed the various authors whom he quoted, so that we could look to them for future discussions. The subject of wheel-wabble is very important, and we should have more papers dealing with it.

DR. H. C. DICKINSON:—I should like to say a few words from the point of view of fundamental mechanics as distinct from that of practical steering-system design. This refers only to wheel-wabble of the kind that has a definite period of oscillation and not to motions that represent merely reactions of road roughness on the steering mechanism. This kind of wabble occurs on smooth as well as on rough roads and, being a periodic oscillation, certain underlying principles must apply to it, whatever the detailed forces involved may be.

First, for a system to continue to vibrate, it must have a free period of its own; in other words, it must follow somewhat the same laws as the pendulum follows; it must have a tendency to return to its normal position when forced out of that position. That is the first requisite for wabble to occur. The second essential is that, when the system is forced out of its normal position, there be some actuating force involved, other than its normal force of restitution, that maintains the periodic motion. The third essential is that the total friction, or damping, be no greater than the total force that tends to maintain the motion.

Scores of different forces may be involved; the system as a whole is complicated. It might simplify matters to consider the relation that the three essentials bear to the problem in hand. First, I think I am right in saying that steering-wheels could not wabble if the center of rotation of the wheel passed through the center of support on the road; that is, if there were no castering action whatever, wheel-wabble could not occur. Another condition under which it cannot occur is when the steer-

ing-gear is irreversible. If there is no lost motion, a completely irreversible wheel cannot wabble. A third thing that could absolutely prevent wabble is having the resistance to motion, that is, the friction in the steering-gear, greater than any force applied tending to maintain the vibration of the system. Those three conditions would absolutely prevent wabble. Probably none of them is desirable in a steering system; therefore, perhaps wabble cannot be prevented in that way.

Of the possible causes that have been discussed, most of them are matters of degree rather than of kind; that is, a change in the amount of caster action, a change in the angle of the wheel and a change in the amount of friction all tend to increase or decrease the tendency to wabble. None of them eliminates it. If there is a force tending to produce wabble and it is only just sufficient to maintain the wabble, when we increase the friction or decrease the caster action, the particular steering-system will cease to wabble.

In a steering-system that has caster action and is not irreversible, certain forces are always involved that tend to maintain the wabbling motion; at least, there may be such forces. One of them has been referred to, namely, the tendency of the driver to hold the steering-wheel very rigidly. Under such a condition, a force is introduced that may maintain a periodic oscillation. If that occurs, the wheels can continue to wabble, provided always that the friction is not greater than the force applied. Wabble from this cause will stop as soon as the driver releases the steering-wheel.

A second source of forces that can maintain wabble is the moment produced about the steering center by the friction of the wheel on the ground when it is turned away from the normal position. The forces set up in this way may be of considerable magnitude.

A third obvious source of energy that might maintain wheel-wabble is the reaction produced when a car begins to "shimmy" or oscillate from side. The abnormal

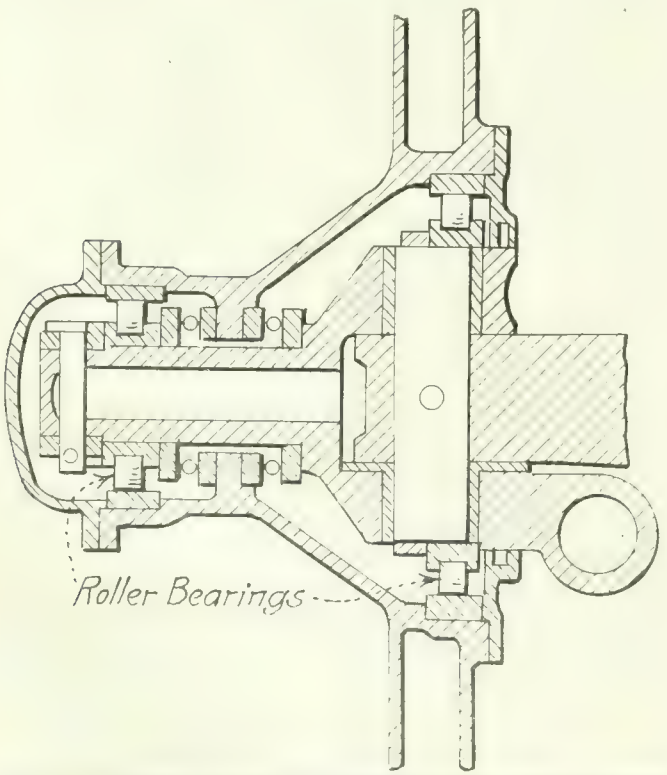


FIG. 31—DIAGRAM SHOWING THE NECESSITY FOR A LARGE-DIAMETER INNER BALL OR ROLLER BEARING

periodic side-sway of the car itself under this condition introduces a turning-moment about the steering-knuckle pin that, if it happens to fall at a certain period, can maintain wabble of the wheels. It may be of value in studying this problem to hark back occasionally to the underlying principles that must govern it and check-up how the actual forces involved are related to the underlying principles of simple harmonic vibration.

DAVID FERGUSON:—Mr. Chase's paper and the discussion should result in clearing-up many points about which there is much misunderstanding at present. There is no doubt of the desirability of the so-called center-point steering, and it is generally conceded that such types as the old Marmon and the suggested designs of W. J. P. Moore are too expensive and bulky; many such designs have been in production and abandoned. A. L. Riker had a very similar design in his electric cars built over 26 years ago. The Leyland Co., in England, used a design almost identical with Mr. Moore's suggestion on all their motor trucks up to about 8 years ago, when it adopted the more conventional design.

It is apparent from Fig. 31 what a large-diameter inner roller or ball-bearing is necessary. Mr. Moore's sketches are apparently diagrammatic, it being impossible to assemble the stub axles on the spherical ends of the I-beam axle as shown. The length of the bearing indicated on the ends of the I-beam axle are much too short for long life and freedom from wear. When these are made adequate to resist the load due to the front wheel striking a rut or a curb sideways, the size of the large ball-bearing will be excessive.

These designs are all shown with a horizontal stub-axle. This looks very bad in practice, due to the roads being made with considerable camber for drainage and it being desired to have the wheels run in a plane radial to this curved surface, or due to the early adoption of the artillery wheel with the rather pronounced dish that used to be given to the spokes so as to make the wheels stronger sideways, the lower spokes being kept vertical by sloping the stub axles. It has become the universal practice to slope the front stub-axles from 1½ to 3 deg., and a car with horizontal stub-axles looks as though the front axle had sagged and allowed the wheels to assume a knock-kneed position. This would actually be so, as the I-beam axle will deflect considerably on account of the load on it. Any play in the vertical pivot-pins or the wheel bearings will give an additional slope to the wheels; so, it is desirable to give almost 1 deg. of slope to the stub-axles to make the wheels run in a vertical position on a flat cross-sectioned road and they should have at least 1 deg. additional slope to compensate for the usual camber on roads. Some manufacturers make the rear axle with sloping wheels also, although this is very exceptional, because of the expense and complication involved. But the front stub-axles can be made to slope just as easily as they can be made horizontal, when of conventional design, and a little extra slope gives a very rakish appearance to the car and has the distinct advantage of lessening the distance from the center of the tire to the pivot-pins, besides giving a considerable increase to the steering lock with standard tread at the tire contact with the road.

The inclined knuckle-pin shown in Fig. 10 of the paper is a very simple and inexpensive means of accomplishing so-called center-pivot steering, the only disadvantage being the alleged tendency for wheel-wabble, and the raising of the car when the front wheels are turned as in Fig. 32. By drawing these diagrams to scale it will be seen that, when the front wheels are turned through an angle of 90 deg., the I-beam axle being assumed to remain

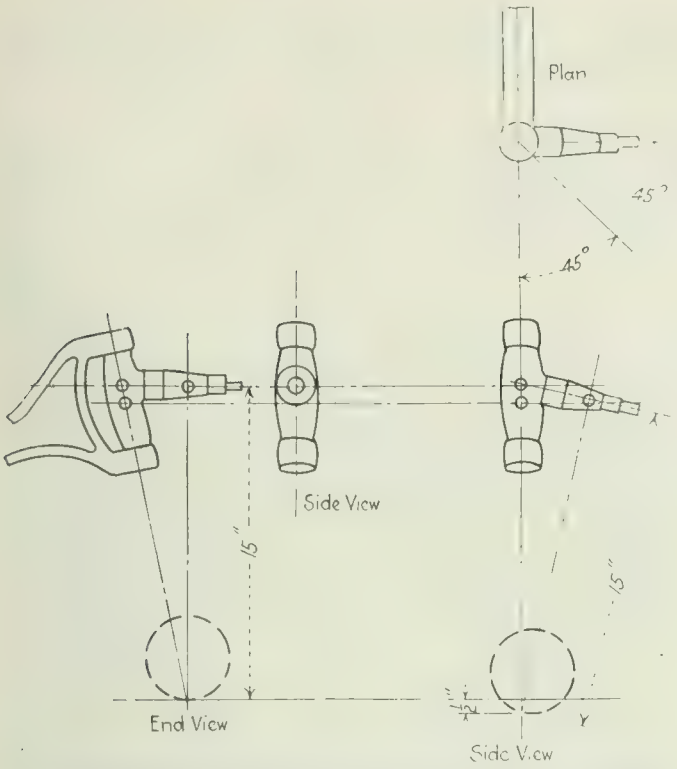


FIG. 32—DIAGRAM ILLUSTRATING HOW A CAR IS RAISED SLIGHTLY WHEN THE FRONT WHEELS ARE TURNED

at the same height from the ground, the wheels will sink into the ground ½ in. Of course, it is impossible in practice to turn the wheels through a greater angle than about 45 deg., in which case both front wheels would sink into the ground ¼ in. Since the ground is fixed, the whole front of the car, including axles and wheels, will be raised ¼ in. This must make steering more difficult than with vertical pivot-pins and center-point steering, though it will have the advantage of a greater self-righting tendency.

Were it not for the fact that motor-car companies feel they have to conform to public taste in regard to wheels, some demanding wood, some wire and some disc wheels, it would be very simple to obtain center-point steering with vertical pivots by adopting single-plate disc-wheels, though I believe a well-made wood wheel is the best type. On the other hand, a steel-disc wheel is preferable to a poorly made wood wheel. One prominent builder has already pinned his faith to disc wheels by adopting a design that will not permit of using wood or wire wheels, without changing the tread. Fig. 33 illustrates this design, the dotted disc-wheel and tire showing it as now being manufactured and the full-line disc-wheel and tire indicates a proposed means to give center-pivot steering with vertical pivot-pins. Of course, the hub flange should be moved farther out to give increased dish to the disc wheel.

There are two objections to this design. It necessitates an I-beam axle 3 in. longer, retaining the 56-in. tread, giving increased weight, and it increases the load on the inner bearing of the wheel. It might be argued that the ease of steering of the present excellent design, in which the projected center-line of the pivot-pin is only 1½ in. away from the center of the tire at the ground, would not be bettered enough in the suggested design to warrant the changes specified. It is possible that this is so, unless front-wheel brakes were to be used, in which case approximate center-point steering is very desirable. The single-plate disc-wheel lends itself to accomplishing this without any great change to conventional designs of steering-pivot axles and hubs.

MR. CHASE:—Mr. Libby expresses the view that I should have listed the various authors from whom information was obtained in preparing the paper. Several are so listed. The bulk of my material was obtained, however, through conversations with various engineers and from letters in answer to a questionnaire that I sent out. In a majority of cases the information secured was not original with the person who furnished it, except perhaps as to certain personal experiences that go to prove a general rule, but is a part of the common knowledge of the subject.

Take the communication that was read by Mr. Myers, for example. In it he made three main points concerning wheel-wabble

(1) Effect of divergent arcs described by the drag-link and the spring
(2) Effect of lost-motion
(3) Effect of unbalanced wheels

Doubtless Mr. Myers has had considerable experience with all of these phenomena, as have many other engineers. All of them are referred to in an article in *Autocar*,[15] which is itself a summary of several earlier articles on wabble in the same publication. Mr. Clayden

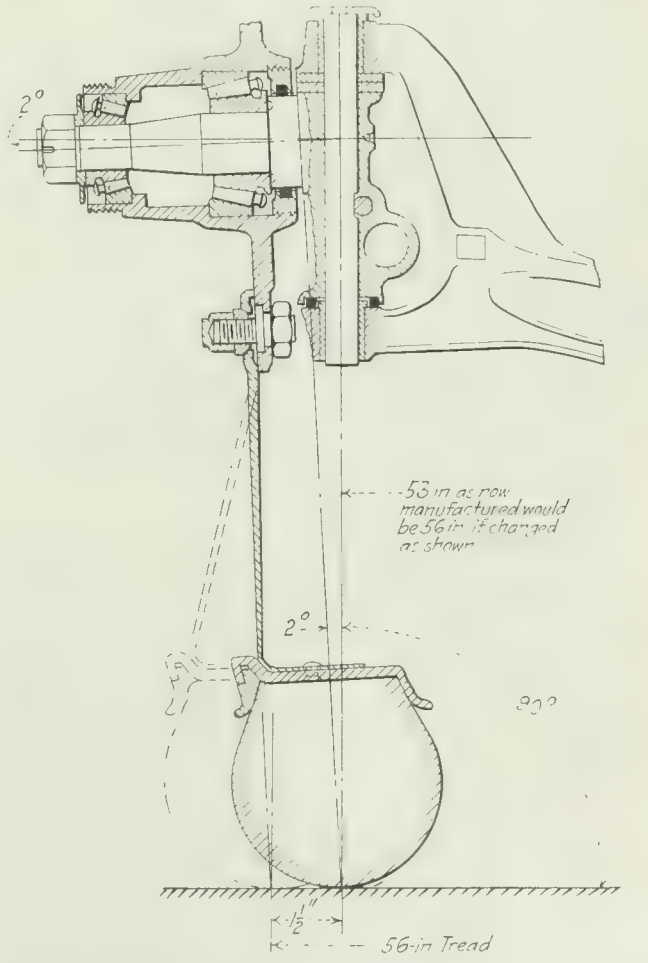


FIG. 33—DRAWING ILLUSTRATING THE STEERING-PIVOT CONSTRUCTION ADOPTED BY ONE AMERICAN AUTOMOBILE COMPANY

The Dotted Lines Show the Disc-Wheel and Tire Arrangement Now Used, While a Proposed Construction To Give Center-Point Steering with Vertical Pivot-Pins and Also Using a Disc-Wheel Is Indicated by the Full Lines

[15] See *Autocar*, July 7, 1922, p. 50.

in an article cited in my paper and discussed by Mr. Myers refers to unbalanced wheels as a cause of wabble and the same thing is referred to in *Motor Age*.[16] References to the effect of drag-link and spring-arc divergence were made in *Horseless Age* nearly 15 years ago and many later references can be found in *Automotive Industries* to this and to the effect of lost-motion in accentuating wabble.

In short, these are matters of common knowledge among engineers familiar with the art, so that no author who attempted anything approaching a thorough survey of the subject could possibly overlook them in preparing a paper of this kind. It probably would require months of study to find who first discovered the numerous facts that I have assembled. Hence, I have not attempted to give the sources of my information except in a few cases where I was fortunate enough to find a printed article that dealt at some length with a particular phase of the general subject. In numerous cases the information on one topic came from several sources and in others I have simply put isolated facts together and drawn my own conclusions, as would any engineer under similar circumstances.

Among those who furnished data on the various subjects treated in the paper were President B. B. Bachman, Dr. H. C. Dickinson, H. M. Crane, J. G. Vincent, A. L. Clayden, C. T. Myers and George P. Dorris. Some of the communications I had were verbal and others were written.

I cannot say that I agree with Mr. Myers in what I gather is his belief that the caster angle has little or no effect upon wabbling. There is abundant evidence that it has a pronounced effect. I have given such evidence in my paper and it has been confirmed in the foregoing discussion. It has been found in numerous instances that slightly changing the caster angle without changing anything else will cure wabble or render it inappreciable.

One communication that I received when gathering material for my paper was from an engineer who had tried several different caster-angles with his car. He found that up to about 3 deg. there was little trouble from wabble, but that angles in excess of 3 deg. produced serious wabble. When he made the caster angle as high as 10 deg., it was impossible to steer the car at all; it was completely out of control. However, there are cars that run successfully with caster angles as high as 6 deg., although some of these cars have been known to suffer from wabble trouble.

The matter of anti-friction bearings, raised by Mr. Horine, is pertinent. I do not mean to say that I invariably favor anti-friction bearings on the knuckle-spindle. That they can be used successfully seems to be indicated by the fact that they are used on many of the cars that are supposed to be among the best-designed cars produced. I am inclined to doubt whether they are desirable on trucks. The fault, that Mr. Horine pointed out, of their tendency to become corrugated, is certainly more or less serious, but I have no doubt that, if the size of the bearings is sufficient, this disadvantage can be overcome, or at least reduced to so small a minimum that it will not cause any trouble. I trust that, for the benefit of the other members, Mr. Horine will disclose the formula on the basis of which the proper amount of foregather can be computed. I have never seen such a formula and, if one exists, I would like to know where it can be found.

I am not familiar with the steering-system used on the Schneider buses, and so cannot discuss the point raised in that connection. I realize, however, that the angular position of the tie-rod arms has an important effect and have so indicated in my paper. The angle should be varied according to the wheelbase, as Mr. Horine indicates. The points brought out by Mr. Pomeroy are of interest in this connection.

The matter of the layout of the drag-link is a geometrical problem, and there is no doubt that there are a number of different layouts that are satisfactory. The best is the one that results in the least deviation of the two arcs described respectively about the center of the spring pivot and the center of the ball on the end of the steering-arm with the drag-link center-distance as a radius. The design in which the steering-gear is forward of the axle, as shown in Fig. 15 of the paper, is an excellent arrangement, especially when the space available for the steering-gear is small. Considering the short drag-link, I think the arrangement can hardly be bettered.

Whether it is better to pivot the front spring at the rear and put the shackle at the front is something of a question. I have no doubt that this is desirable under certain circumstances. One of the latest designs of American car that is not yet in production has such a layout. I think that it would be better to shackle the spring at the front end but that when the steering-gear arm is back of the front axle, as it is in Fig. 15 and in some other designs, it would be better to shackle the spring at its rear end. Like Mr. Pomeroy, I am unable to say why front springs are so seldom shackled at their forward ends, when the position of the steering-gear lever is, in a great majority of cases, well to the rear of the axle.

The point brought up by Mr. Burkhardt in respect to the lack of damping tendency of the off wheel in a car with transversely raked pivots arranged to give center-point steering is well taken. A center-point layout is said by some to make the steering easier but, as Mr. Burkhardt says, when one wheel starts to wabble with this construction the other wheel does not offer a counteracting moment, tending to prevent wabble as it does when the pivot is off-center. Whether center-point steering actually is more easily controlled than the other type, I am unable to say.

The point made by Mr. Horine to the effect that with the center-point layout the tire must be twisted about a central point as against rolling it about a central point, when there is an offset knuckle, is worth consideration. There is, however, in either case a considerable twisting action on the tire and I doubt whether there is a noticeable difference when the vehicle is in motion. Some cars with center-point steering certainly do have wonderfully free steering action when they are stationary.

Mr. Scaife raises the point that the ball of a ball-and-socket joint wears out-of-true. That does occur but if particular attention is paid to the lubrication such wear can be minimized. Furthermore, I do not see that it should be any more difficult to replace a worn ball than to replace a worn pin or the bushings when a yoke construction is employed. With the spring-backed socket-type, the play of course is continually taken-up; hence the ball type has the distinct advantage that it tends to eliminate rattle. As Mr. Pomeroy pointed out, it is absolutely necessary to use the ball type when the transversely raked pivot is employed.

The matter of the layout of the tie-rod arms, raised by Mr. Pomeroy, is interesting; it is a geometrical problem; several papers have been written on the subject, one or two of which are referred to in the paper. The general impression is that the best layout is the one in which the extension of the center-lines meet at the center of the

[16] See *Motor Age*, Nov. 16, 1922, p. 22.

rear axle. Some state that a little better layout is obtained by bringing that point somewhat forward of the rear-axle, but I was not aware that any one brought it as far forward as Mr. Pomeroy indicates that he has found to be desirable.

Dr. Dickinson said, "If there were no castering action whatever, wheel-wabble could not occur. . . . Another condition under which it cannot occur is when the steering gear is irreversible." I think he is correct in-so-far as he refers to certain periodic tendencies to wabble. It is undoubtedly true, however, that it is possible to produce wabble by having a faulty drag-link layout, or by having a wheel that is badly out-of-balance, even with castering and with an irreversible gear.

MR. MYERS:—I do not want it understod that I believe the castering action has no effect on the wheel-wabble. In my experience it has been possible to use the castering action up to about 2 deg., varying anywhere from 1½ to 2½ deg., without any bad effects, so long as the other points are taken care of.

SEVENTH SEMI-ANNUAL GASOLINE SURVEY

FOR a number of years the Bureau of Mines has conducted semi-annual surveys to determine the changes in motor gasoline being sold in the United States. The present survey shows that the tendency toward an increase in volatility that was noted 6 months ago is still present, and that the seasonal variation from summer to winter grades is apparently slowly decreasing. A careful review of the data obtained in the previous surveys, beginning with that of 1917, shows that there is a tendency toward a greater uniformity in the character of the gasoline marketed in the United States, as shown by the figures in Table 1, which were obtained by averaging the end-points of the least volatile and the most volatile samples of gasoline. For example, of the 850 samples analyzed in 1919, the 10 per cent of the samples having the highest end-points and the 10 per cent having the lowest end-points were grouped, and the end-points of each group averaged. These averages are represented in the table as the "Maximum 10 Per Cent" and the "Minimum 10 Per Cent" respectively. The same process was used on the other surveys. An examination of the "Differences" shows that the range of "end-points" in each survey is less than in the previous one, indicating a tendency toward uniformity.

TABLE 1—RANGE OF END-POINTS IN EACH GASOLINE SURVEY

Date	Maximum 10 Per Cent, Deg. Fahr.	Minimum 10 Per Cent, Deg. Fahr.	Differences, Deg. Fahr.
April, 1917	449	334	115
April, 1919	472	363	109
January, 1920	482	377	105
July, 1920	502	406	96
January, 1921	467	382	85
July, 1921	473	398	75
January, 1922	461	397	64
July, 1922	461	401	60
January, 1923	451	397	54

In the present survey, taking the cities individually, there are some distinct changes noted. In comparison with January, 1922, the average for the City of Washington shows an increase of 20 deg. in the initial boiling point and a decrease of 12 deg. in the 90 per cent point. The averages for Pittsburgh, Chicago and St. Louis each show consistent drops throughout the distillation range with the exception of the initial boiling point, which was increased slightly. On the other hand, the averages for Salt Lake City and San Francisco indicate, on the whole, a decrease in volatility. The average 90 per cent point and the end-point of the San Francisco samples each rose 11 deg., while the same points of the Salt Lake City samples rose 8 and 2 deg. respectively. In the distillation of the samples from Pittsburgh and St. Louis it was found impossible to recover even 90 per cent of some samples when using a mixture of ice and water in the condenser bath according to the standard method of distillation. This would indicate that these samples contain an excess of low-boiling fractions, which is probably due to an admixture of an excess of natural-gas gasoline.

A distillation curve was plotted representing the grand average of all the analyses for the January, 1923, survey, together with one that represents a motor gasoline meeting Federal specifications. The average survey curve falls well below that representing Federal specifications, but it conforms very closely in shape to the specification curve.

In the present survey the samples were tested in accordance with the methods given in Bureau of Mines Technical Paper 214, entitled Motor Gasoline; Properties, Laboratory Methods of Testing and Practical Specifications, by E. W. Dean. The actual specific gravity at 60 deg. fahr., the corresponding degrees according to the American Petroleum Institute scale, the initial boiling point or first drop, the 20, 50 and 90 per cent points, the end-point, the average boiling point and the per cent recovered in the receiver were determined. The average figures for each city are shown in Table 2.—From a report prepared by N. F. LeJeune and L. G. Marsh, of the Bureau of Mines.

TABLE 2—AVERAGE RESULTS OF THE JANUARY, 1923, MOTOR-GASOLINE SURVEY

District	Specific Gravity	American Petroleum Institute, Degrees	Temperature, Deg. Fahr.: First Drop	20 Per Cent	50 Per Cent	90 Per Cent	End-Point	Average Boiling Point	Amount Recovered, Per Cent
New York City	0.739	60.0	101	201	270	368	420	267	96.3
City of Washington	0.758	55.3	118	202	261	368	424	267	96.8
Pittsburgh	0.729	63.0	95	171	244	382	423	249	92.8
Chicago	0.745	58.4	107	202	268	379	433	271	96.5
New Orleans, La.	0.743	58.9	117	213	280	376	428	278	96.9
St. Louis	0.736	60.8	103	196	269	382	433	268	95.4
Bartlesville, Okla.	0.742	59.3	109	205	273	381	440	274	96.4
Denver, Colo.	0.744	58.6	109	205	273	369	419	270	96.5
Salt Lake City, Utah	0.742	59.4	98	199	265	370	414	264	95.7
San Francisco	0.759	54.9	113	207	265	370	432	269	97.3
Average	0.744	58.8	107	201	267	375	427	268	96.0

[1] Failed to meet the specifications for Federal purchases adopted Feb. 3, 1922, and revised Oct. 31, 1922.

SOCIETY MEETINGS

GENERAL-PURPOSE FARM TRACTORS

Will Feature National Tractor Meeting in Chicago This Month

Arrangements have been made definitely to hold a national Tractor Meeting of the Society in Chicago at the Auditorium Hotel on Thursday, April 19. This date just precedes an important meeting of the Farm Equipment Manufacturers Association. Two engineering sessions will be held, one in the morning and the other in the afternoon. The morning session will start at 10 o'clock and the afternoon session at 2.30 p. m. An informal Tractor Luncheon has been arranged during the noon period between these two meetings, this forming the social feature of the meeting.

Prof. O. W. Sjogren of the University of Nebraska faculty will read a very important paper in the morning meeting. This paper will set down constructive criticism of an engineering character that has come to light as a result of the extensive tractor tests conducted at the University of Nebraska for the State. These tests are widely known and respected for the unprejudiced manner in which the ability of various types and makes of farm tractor is determined. Professor Sjogren has been in charge of this tractor testing work and his paper is prepared with an altruistic motive in mind; he wishes to place before the industry the outstanding engineering faults of the tractors that he has tested for the purpose of encouraging engineering development and a greater perfection of the tractor as a farm implement.

The afternoon meeting will be addressed by C. M. Eason. Mr. Eason is well known in the tractor industry, having been connected with it for a number of years, serving at one time as vice-president of the Samson Tractor Co. Mr. Eason is an enthusiastic advocate of the general-purpose type of farm tractor capable of doing all of the work now done on the farm by horses. He will record some of the progress that has been made in the development of this type of machine and will illustrate his talk with numerous photographs. As a part of his paper, Mr. Eason has collected the opinions and experiences of a large number of representative tractor engineers and these will form an important contribution to the discussion.

Tickets for the luncheon may be ordered from the New York City office using the blanks soon to be forwarded to the members with a special issue of the *Meetings Bulletin*. The tickets are priced at $2 per plate. It is intended that the luncheon gathering will be addressed by an eminent agriculturist whose views on farm economics will form both an interesting and educational diversion from the engineering talks of the morning and the afternoon. It is expected that the Tractor Meeting will be attended by a representative group of tractor engineers because of its location in the center of the tractor building territory and its being scheduled just previous to another important activity of the tractor industry.

MOTOR TRANSPORT APRIL FEATURE

National Meeting in Cleveland Devoted to Truck, Bus and Taxi Operation

Operation experience in three important fields of automotive transportation will be featured in the National meeting of the Society at Cleveland, April 26 to 28. In some respects this meeting is a departure from the lines of activity followed by the Society in the past; we are to enter the field of operation in an active way. Practically all of the discussion and the papers will be built around problems of operation; some time, of course, will be devoted to maintenance as well. The operation of the motor truck, motorbus and the taxicab will be touched upon; there are important and valuable papers on each of these three means of commercial transportation. A glance at the program on the opposite page reveals the importance of the several papers and in each instance, the author's connection indicates that he is able to speak with authority on operation problems.

The combination of valuable papers, a central meeting location, reduced railroad fares, and the opportunity to meet representative men engaged in the operation of motor-vehicle fleets, should prove sufficiently attractive to lead every executive and engineer to attend the Automotive Transportation Meeting, April 26 to 28, in Cleveland. All of the meetings and the Transportation Dinner will be held at the Hotel Winton. Reservations for rooms may be made by addressing the hotel authorities direct. Garage facilities are ample and reservations may also be made for the storage of your car if you decide to drive to Cleveland.

At the time of writing this announcement, the scheduling of the several papers has not been determined upon; this is largely because of the fact that additional contributions are expected. The definite schedule of meeting periods and presentations will reach all of the members of the Society through a special issue of the *Meetings Bulletin* about April 17.

The large amount of material available on motor-truck, motorbus and taxicab operation made it necessary to eliminate consideration of the motor rail-car from the program of this Cleveland Meeting. Each of the other mediums of commercial automotive transportation will receive full consideration and discussion. It is planned to have a representative engineer of a vehicle manufacturing plant assigned to the discussion of each of the papers. The names of these discussers will be announced in the special *Meetings Bulletin* referred to above.

The technical sessions will be held during the morning and afternoon of April 26 and 27. The Automotive Transportation Dinner will be held at the Hotel Winton on Thursday evening, April 26. It is hoped to secure an outstanding public official who is interested in the extension of automotive transportation to speak at the dinner. A card for the making of dinner reservations will be forwarded to the members in the near future. Visits of inspection will be made to the factories of the White Motor Co. and the Nela Park Laboratories of the National Electric Lamp Association. It is probable that these visits will be arranged on Saturday morning, April 28.

The Society intends to give a large amount of publicity to this meeting among motor-truck operators, traffic and engineering departments of the railroads, and the electric traction companies. This will be done for the specific purpose of bringing to the meeting a large and representative group of commercial motor-vehicle users so that they may meet and exchange views with the engineers and constructors of this equipment. A study of the present status of automotive transportation evidences great need for such a cooperative gathering. Those directing the arrangements for the meeting have already noticed a widespread interest in it among the users; it is to be hoped that an equally great enthusiasm and interest will be shown by those in the industry who are concerned with the production of the motor-vehicle equipment.

Mark the date of the Automotive Transportation Meeting on your calendar at once; make arrangements to attend the meeting in person and bring with you all those members

of your staff who should and must become more closely allied with the purchasers and the operators of commercial motor vehicles made by your organization.

PAINT AND VARNISH TROUBLES

Form Subject of Instructive and Largely Attended Detroit Section Meeting

Painting and varnish troubles were discussed in a very comprehensive manner at the meeting of the Detroit Section of the Society on March 2 which attracted over 265 members and guests. L. Valentine Pulsifer, chief chemist of Valentine & Co., was the speaker of the evening. He presented the salient points taken from his two previous addresses before national body engineering meetings of the Society. These papers appeared in THE JOURNAL for January, 1922 and January, 1923. The speaker particularly stressed simple methods of testing varnishes that enable one to determine their durability, elasticity and other important qualities.

An innovation was tried at this meeting of the Detroit Section. Cards were passed through the audience on which questions were written by those in attendance; the questions were collected, then read by the chairman in rapid-fire fashion and answered by Mr. Pulsifer. These questions and answers formed at least as valuable a part of the meeting as the paper itself. Appreciating that the information given in the answers was timely and of great interest to those in the production end of the industry, these were edited promptly by Mr. Pulsifer and will be found on p. 335 of this issue of THE JOURNAL.

The next meeting of the Detroit Section will be held on April 6 in the General Motors Building starting at 8 o'clock. The subject of the meeting will be Gear Grinding. Glenn Muffly will read the paper of the evening which will be descriptive of one type of gear-grinding machine and he will also include a discussion of some peculiarities of the involute form of gear tooth. Mr. Muffly's talk will be followed by a period for written questions and for open discussion. The meeting will be preceded by the customary informal dinner at 6.30 p. m., which is always a feature of Detroit Section meetings, there being 140 seated at the March dinner.

MINNEAPOLIS DISCUSSES AIRPLANES

The Minneapolis Section had a varied program at its meeting on March 7. The Modern Type of Airplane formed the topic of a paper by Charles Boehnlein of the engineering faculty of the University of Minnesota. Mr. Boehnlein's paper described some of the airplanes competing in the Pulitzer races at Detroit and the author showed slides reproduced from photographs of the competing planes that he had taken at Selfridge Field. J. D. Mooney, engineer of the Auto Engine Works of St. Paul, read a paper on Airplane Engines in Motorboat Service. Mr. Mooney compared the characteristics of the two types of engines and showed the similar and dissimilar conditions of operation in the two classes of service. Dean Leland of the University of Minnesota addressed the Section briefly on the advantage of local engineering meetings.

The two papers elicited active discussion in which A. W. Scarratt, A. F. Moyer, J. W. Wagner, Victor Gauvreau, A. H. Bates and others were prominent.

AUTOMOBILE VALUES INCREASED

Schipper Believes Public Received This Impression at the Shows

Impressions left by the New York and Chicago Automobile Shows were summarized in a very interesting paper prepared by J. Edward Schipper and read at the meeting of the Buffalo Section on March 16. Unfortunately, Mr. Schipper

AUTOMOTIVE TRANSPORTATION MEETING

Cleveland—April 26-28

TENTATIVE LIST OF SPEAKERS

F. C. HORNER
GENERAL MOTORS CORPORATION

The field for the motor truck in railroad terminal cartage service. Greater load efficiency through scientific cartage control. The unit container. Description of English railway cartage practice. Will include films showing cartage operations of two stations in London.

S. G. THOMPSON—A. J. SCAIFE
WHITE MOTOR CO.

Presentation of a motor-truck company's transportation engineers' recommendations for economic control of truck fleet operation. Covers experience gained from practical operation in many fields.

S. VON AMMON
BUREAU OF STANDARDS

Presentation of results of exhaustive tests of motor-truck rear-axles of all types, conducted for the Army Motor Transport Corps. Data on relative efficiency of worm and internal-gear types an important part of paper.

MAJOR BRAINERD TAYLOR
MOTOR TRANSPORT CORPS

Recommended methods of motor-truck traffic control based on plan evolved by the Army for use in case of national tie-up of rail transportation. Includes valuable experience of army transport in France.

J. F. MURPHY
COLUMBIA TERMINALS CO.

Describes operations of organization engaged in the transfer of inbound and outbound freight between nine railroad depots in St. Louis. Has developed a system of motor haulage that amounts to the operation of off-track railroad facilities through congested industrial sections.

C. D. EMMONS
UNITED RAILWAYS & ELECTRIC CO. OF BALTIMORE

Mr. Emmons is president of the American Electric Railway Association and actively interested in the operation of street cars, motor buses and trackless trolleys. He has spent several months abroad studying urban transportation in the large Continental cities.

PAUL H. GEYSER
YELLOW CAB MFG. CO.

Mr. Geyser has been connected with the development of taxicab transportation for many years. He will present his recommendations on systems of taxicab operation and maintenance. Design requirements for taxicab service will be outlined.

HAROLD B. WESS
R. H. MACY & CO.

Mr. Wess is chairman of the Retail Merchants Delivery Association, an organization that has been promoting a comprehensive research study of motor-truck operation in the retail delivery field. He will describe some of the results accomplished to date.

was unable to attend and his paper was read by J. C. Talcott. Some of the impressions of the author are abstracted in the following paragraphs.

While improved equipment was probably the outstanding feature of the cars at the Shows, it is only a small part of a big movement that has progressed during the past decade. This movement has been one of greater attention to detail. It is not possible to name a part on which attention to detail has not been more carefully focused than ever before. Quality of cars has improved notably; yet, improved production methods and manufacturing economies have made it possible to produce present-day automobiles and sell them at relatively low prices. Improved machinery and methods have reduced the labor-cost per car by reducing the number of hours of labor required to build it, rather than by reducing wages. The elapsed time from the raw material to the finished car has been greatly reduced, with a proportionate saving in carrying charges or overhead. The strongest impression left by the Shows was this ability of the manufacturer to provide the public with better cars at more reasonable prices. Raw materials are better, methods of manufacture are improved, inspections are more exacting, assembly is more carefully conducted and yet cars can be purchased for about the same money as in the pre-war period. If we had made the same automobile in 1914 as that produced today, it is safe to say that prices would be at least 35 to 50 per cent higher. The war rendered a service to the automotive manufacturing business which cannot be under-estimated. The advances made as a direct result of the war represent a development period which would have extended over a great number of years.

The engineer has realized that a product must be designed not only for performance but also for manufacture. There is greater cooperation between the chief engineer and the production manager; this has resulted in a decreased manufacturing cost. Costs have been further reduced by the introduction of special labor-saving machinery. The high cost of much of this machinery has emphasized the necessity for limiting design changes that would render these expensive machine-tools obsolete and this condition has been responsible for a certain stability in design.

Superior engine performance has been sought and attained in various ways as evidenced by the Show exhibits. Reciprocating weights have been reduced, the crankshafts made more rigid and the crankcases made stiffer; this progress has aimed at the elimination of vibration. Another marked tendency in engine design is the use of longer pistons with increased bearing areas that reduce the unit side-pressure on the cylinder walls. A strong tendency was noted toward the more complete use of the complete-pressure system of lubrication. Increased rigidity in structure is not confined to the engine. In going over the 1923 models one notes how many companies have increased the rigidity of the chassis frame. Coupled with this, a stronger body construction has been adopted by many manufacturers.

Service and maintenance charges have been greatly reduced. This is due to improved materials; rendering adjustments and lubrication easier, so that the owner will give them proper attention; and, units that must be removed for adjustment at comparatively frequent intervals have been especially accessible. The detachable cylinder-head has become almost universal practice.

A very active discussion on methods of machining and fitting crankshaft bearings followed the reading of the paper. Some doubt was expressed by David Fergusson and O. M. Burkhardt about the wearing qualities of crankshaft bearings that were machined to interchangeable limits and fitted in the case and to the crankshaft without any hand-work. R. W. A. Brewer made a plea for lighter construction in passenger vehicles; he felt that the present tendency was to continue the production of automobiles that were too heavy for economical operation.

The next meeting of the Buffalo Section will be held in the rooms of the Buffalo Engineering Society, Hotel Iroquois, on April 13. Motion pictures depicting the construction and operation of electric starting, lighting and ignition systems will be shown, accompanied by a talk by C. F. Bishop.

JORDAN TALKS PAINT PSYCHOLOGY

Cleveland Section Will Visit Paint Factory as Part of April Program

The sales value of clothing a motor car in an attractive coat of paint is respected by most motor-car salesmen. The psychology underlying this sales appeal is an interesting study. E. S. Jordan, president of the Jordan Motor Car Co., through his intimate contact with the motor-buying public, has formed some very interesting opinions and theories on paint psychology. He will present them before the Cleveland Section of the Society on the evening of April 10 at the rooms of the Cleveland Engineering Society in the Hotel Winton. Mr. Jordan's talks are always crowded with good logic on motor-car merchandising and much of this will appeal to the engineer. His inimitable manner of presentation makes his talks attractive from the entertainment as well as the educational standpoint.

As a part of its activity on the paint subject, the Cleveland Section has arranged a visit to the manufacturing plant of the Sherwin-Williams Co. during the afternoon preceding the meeting. This visit takes place on Tuesday afternoon, April 10. Members of the Sherwin-Williams staff will serve as guides and will explain all of the details of paint and varnish manufacture. This provides an unusual opportunity for motor-car engineers, body designers and production men to acquaint themselves with the ingredients used in paint and varnish manufacture as well as the methods of preparing and mixing them.

MORE ENGINEERING NEEDED IN SERVICE

Service Authority Believes Maintenance Work Will Profit as a Result

Making a plea for more engineering in automotive maintenance, H. R. Cobleigh presented a very interesting argument to the Washington Section at its meeting on March 2. The subject of his address was Automotive Maintenance Engineering—A New and Inviting Field. As Secretary of Service of the National Automobile Chamber of Commerce, Mr. Cobleigh has had an opportunity to visit many service establishments and his observations have enabled him to formulate some valuable opinions. The following paragraphs give some of the important points brought out in his talk.

Engineering is doing anything scientifically and efficiently as contrasted with simply doing it. The definition indicates exactly the difference between service as we now know it and what it will become when simplified to the status of maintenance engineering. The execution of work in the repair shop must be studied and ways contrived for performing it as efficiently as in the original construction in the car manufacturing process. If cars were built as inefficiently as they are overhauled they would cost about four times their present price. If they could be overhauled as efficiently as they are built, the work could be done for one-quarter its present cost. While this ideal may not be obtainable, certainly much can be done by concentrating the overhaul work in fewer large shops so that the volume of work handled would justify the installation of labor saving machinery, and processes employed that small shops could not afford. The small shops could confine themselves to minor repairs and adjustments, sending units requiring rebuilding or overhauling to the specialized plants, where this larger work could be done better and quicker at half the cost to the owner, and with an equal profit to the individual shop.

Herein lies a practically untouched field of opportunity in which engineering talent might accomplish a great work along the lines of efficient organization, shop layout and equipment, motion and plan study, special tools and training of operators. Let the engineer begin to study repair shop efficiency and he will find that the average service-station can be 75 per cent properly equipped at a reasonable ex-

Schedule of Sections Meetings

APRIL

4—Minneapolis Section

6—Washington Section—Some Observations on Exhaust-Valves—A. W. S. Herrington

6—Detroit Section—A Process of Gear Grinding and a Discussion of Tooth Forms—Glenn Muffly

10—Cleveland Section—The Psychology of Paint—E. S. Jordan—Visit to the Sherwin-Williams Plant in the afternoon

13—Buffalo Section—Electricity in the Motor Vehicle—C. F. Bishop

16—Detroit Section—André Citroen of Paris, France—The Future of the Light Car

19—Metropolitan Section—Engineering Features of Fleet Operation—Edward E. La Schum

20—Mid-West Section—General Design of Electric Trucks and Their Performance in Urban Work—J. G. Carroll

pense. Adequate tool and fixture equipment will minimize hand-work, employing machine-tool operations in its stead. The flat-rate system is an encouragement to efficiency; incentive is placed in the way of the workmen to reduce the time he spends on a job to earn a bonus. Short-cuts are a natural development and result in more profit to the service-station and less expense to the owner.

Education of shop personnel and the rating of mechanics are subjects deserving the engineers' study. There are too many mechanics in the business who are poorly and inadequately trained; they are unable to develop tools that save time and labor. It is important, and in no sense beneath the engineers' dignity, that he become concerned about the training of the personnel in the service-station.

It has been the habit in the past to throw away a car before its useful life was really exhausted. Obsolescence has had more to do with the scrapping of automobiles than their wearing out. Now that designs have become more or less standard, the public will not indulge in this practice. It will require a longer useful life from properly maintained vehicles, and insist on reasonable maintenance expense. Repair charges that exceed the retail value of the repaired article many times will not be tolerated. The public will never receive this ideal service, however, until the engineer applies himself to the problem with as great sincerity as he has already applied himself to the economics of design and production.

The next meeting of the Washington Section will be held on April 6 at the Cosmos Club starting at 8 o'clock. The meeting will be addressed by A. W. S. Herrington, who will present the results of some extensive engine-valve tests, made by the engineering division of the Motor Transport Corps.

TROLLEY-BUSES AND FLEXIBLE VEHICLES

Metropolitan Section Discusses Cooperation of Street Railway and Automotive Engineers

A very interesting and vitally important meeting was held by the Metropolitan Section at the Automobile Club of America on March 15. It was attended by various representatives of interests vitally concerned in highway passenger-transportation, such as the City of New York, the American Electric Railway Association, bankers and rolling-stock producers.

William P. Kennedy opened the discussion by elucidating the salient points of the paper he had prepared for study before the meeting, entitled Trolley-Buses and "Flexible" Vehicles. This paper, which was of a comprehensive nature, was analytical in the broad sense and recalled to the mind of various members the unusually timely and instructive papers that Mr. Kennedy has presented at meetings of the Society in the past, such as those discussed at 1911 sessions, on Administrative Engineering and Salesmanship in the Commercial-Car Field and Standardization Possibilities in the Commercial-Car Field. It was Mr. Kennedy's purpose in this paper to bring to the attention of automotive engineers the current situation in the street-railway field and to point out to what extent factors are undetermined in the common problems of automotive and street-railway engineers. Mr. Kennedy proceeded on the assumption that new business is to be had in the providing of so-called flexible transportation equipment for street-railway lines, citing such elements as sight-seeing and freight handling, of which there are interesting current examples in Europe. Such equipment can utilize present railway systems and still be independent. It is felt that the street-railways must provide transportation of the flexible type, the design of bus in common use today not being satisfactory in this respect. Important phases of the desired vehicle are one-man operation, a low center-of-gravity and use so far as possible of the power the street-railways can now furnish. Trolley-buses can, of course, be provided with auxiliary equipment such as gas-engines or storage- batteries for propulsion when the trolley is not used; the street-railways have expressed a desire for this. Mr. Kennedy said that the trolley-bus has been used successfully in Europe since 1903, freight-lines being operated. He argued in favor of gas-electric transmission in public passenger-service, claiming that it reduces the cost of operation of vehicles of long life, is quiet, decreases general wear-and-tear and saves brakes. He advocated also using trailers with tractors, mentioning with emphasis the necessity for interchangeability of parts and standardization of units.

Among the places in this country where trolley-buses are operated at present are Baltimore; Minneapolis; Los Angeles; and Staten Island, New York. They are being used also in Toronto, and Windsor, Ont., Canada. The motor used, which is the light street-car type, is too heavy. One model of English trolley-bus has a single motor and worm-gear drive. There is in England also a double-deck bus, with motors attached independently to the driving-wheels.

Mr. Kennedy showed some new designs of tractors and semi-trailers with trolley-motor or gas-engine equipment. The tractor is detachable so that the type of body can be changed easily. The steering is through the rear wheels, controlled by the tractor. The trolley motor-coach has capacity for 100 persons.

G. C. Hecker, special engineer of the American Electric Railway Association, said that the time is ripe for cooperation between street-railway and automotive engineers. He referred to the reported cost of 36 cents per bus-mile of the Fifth Avenue Coach Co.; stating that the best comparison is the cost per passenger carried, this being more than 7 cents in the case of the said company and over 5 cents in street-railway operation. Mr. Hecker said that the trackless-trolley-car should be useful in new territory but that the public must understand that it will have to pay more if bus transportation is more expensive. The lean routes affect the total earnings of companies. The street-railways have a heavy load to carry in the way of taxes and other charges.

Incidentally, Mr. Hecker expressed the belief that the business of the street-railways is greater at present than it has ever been before. Requirements in the design of vehicles for public passenger-transportation are maximum standardization, the greatest feasible comfort, rapid loading and unloading, a satisfactory method of collecting fares in one-man operation, and certain safety arrangements to prevent accidents.

R. E. Fielder, chief engineer of the Fifth Avenue Coach Co., said that the gas-electric transmission did not compare favorably with the mechanical transmission in the service of his company during several years of operation, the acceleration of the former being sluggish, the gasoline consumption higher and the weight greater. He feels that the mechanical transmission is now sufficiently quiet and satisfactory. He said that it is being found that gasoline-bus operation is more economical than the conventional street-car operation; that with one-man operation and without undue taxation a cost of 24 cents per bus-mile is possible.

Speaking to the point made by Mr. Kennedy that due to development in a non-competitive field there had been an unjustified feeling of security until a few years ago on the part of the street-railway operators, C. W. Kellogg, of Stone & Webster, Boston, said that the electric railways have had great problems that spurred them as much as competition could have stimulated them, they having been compelled to exert strenuous efforts to improve and reduce the cost of their service. He summed up his remarks by saying that what it is desired the automotive engineer shall produce is a comfortable, low center-of-gravity vehicle.

F. C. Horner pointed out that motorbuses run on the average as much as 50,000 miles per year, at a greater speed than that of the truck, which travels 6000 to 8000 miles per year. He reported from recent personal observation that there is no increase in the use of trolley-buses abroad, some tramway men whom he interviewed having said that these vehicles have most of the objections of the trolley-car and none of the advantages of the bus. He believed that the field for trolley-buses in this country is limited.

C. J. McPherson, of the J. G. Brill Co., Philadelphia, expressed his understanding that few bus companies, aside from those operating in New York City, Chicago and Detroit, have made money. He made it plain that the street-railway industry must procure a vehicle that can be operated at a profit. Increase of fare means decrease of income. He did not express a definite opinion as to the future of the trackless-trolley-car but said that the regular bus is not what the street-railways need. A storage-battery vehicle, if practicable, would be very advantageous.

Prof. Morton Arendt, of Columbia University, appeared as a representative of New York City, and explained in a vivid and forceful manner what steps have been taken to meet transportation emergencies there. He said that in Baltimore the ordinary trolley, the bus and the trackless-trolley-car are being operated. There is a $2,500 annual tax on a 50-passenger bus. The fare is 10 cents. In New York City, due to the discontinuance of operation of several street-railway lines and the need for crosstown service, permits were issued for bus operation with 5-cent fare under certain stipulated regulations. In operation of these, which continued until it was enjoined by railroad corporations, no complaint was had from bus operators as to not making money on the 5-cent fare. The electric bus has a speed of from 11 to 12 m.p.h. and travels 45 miles on a charge. Professor Arendt said that a vehicle must be had in which the advantages in control of the electric vehicle and those of distance of the gas vehicle are available. The ordinary gasoline-bus is not the solution of transportation in sparse country, in his opinion. He cited the experience on Staten Island, where long routes over hills must be traveled and few passengers are to be transported. The cost per car-mile of the trackless-trolley-car there was $0.256 and of the gasoline truck $0.338. The former figure would be lower in handling a greater amount of traffic. Professor Arendt figures that the advantage is in favor of the trolley-bus to the extent of 10 cents per car-mile, there being no doubt that the overhead construction gives the cheapest transportation for undeveloped territory. He said that the increase in building along the routes of the trackless trolleys had been enormous, the gasoline bus not being so advantageous in this respect as it does not necessarily give promise of permanent operation in outlying districts.

Professor Arendt described and showed views of trackless-trolley-cars that had been designed specially for use in New York City, one design having a 195-in. wheelbase and capacity for 50 passengers, seats being provided for 30 of these. He said that he had seen over 75 people riding in one of these vehicles, which are well-sprung and have better acceleration than gasoline buses.

One very interesting thing Professor Arendt reported was that the City of New York is now installing a trackless-trolley system between the Pelham Bay subway station and City Island. At certain times, 16,000 people are transported per hour on this route. It is proposed that there shall be 25 trackless-trolley-cars in operation there.

Joseph A. Anglada advocated strongly the use of the electric vehicle in the mass transportation of passengers, citing its superiority with respect to long life, ease of control and low cost of maintenance. He mentioned the need for battery-charging sets on the electric vehicle.

Arthur J. Slade presented detailed information as to the trackless-trolley-cars that are being established in the suburbs of Paris, France; also of a new gasoline bus that is 34 ft. long and has three axles and six wheels, the weight being 300 lb. per passenger as compared with 600 in the case of the conventional trolley-car; and provision being made for 48 passengers, standing being permitted on the platform only.

The next meeting of the Metropolitan Section will be devoted to motor-truck operation. Edward E. La Schum, general superintendent of motor-vehicle equipment, American Railway Express Co., will read a paper on the Engineering Features of Fleet Operation. This meeting will be held at the Automobile Club of America on the evening of April 19 starting at 8 o'clock.

MID-WEST SECTION MEETINGS

The Mid-West Section met in Chicago on March 23 and was addressed by F. H. Ford on the subject of road-lighting. As a part of his presentation, Mr. Ford recommended a new type of chart for recording the relative anti-glare value and light distribution qualities of head-lamp lenses. Instead of representing light intensity by lines to indicate photometric values, Mr. Ford's arrangement denotes intensity by varying degrees of tints on the surface of a chart that is supposed to represent the roadway.

The next meeting of the Mid-West Section will be held at the rooms of the Western Society of Engineers, in the Monadnock Building, Chicago, on the evening of April 20. A paper will be read by J. G. Carroll on the General Design of Electric Trucks and Their Performance in Urban Work. This meeting will start at 8 o'clock.

MOTOR MARKET CONDITIONS CHANGING

Selection Replaces Mere Desire in the Psychology of Purchasing

Harry Tipper, business manager of *Automotive Industries*, brought out some interesting developments in the automotive industry on its economic side, in addressing the New England Section at its regular meeting in Boston on March 16.

Mr. Tipper called attention to the gradual change that has taken place in the buyer's reason for wanting a car and its effect on the builder's sales problem. Desire to possess was formerly the principal market, psychologically, for buying. Therefore the company that could deliver a product with sufficient rapidity was bound to get the business. Now the whole market is changing. The item of selection is coming to be more important than the mere possession of a car. That means that we shall have to explain more to the public and put a different kind of pressure in the market. Some firms are losing great possibilities of sales promotion by con-

sidering the business from the sales angle too much and not enough from the buyer's angle. Economically, we have to change the whole outlook and find out what the growing desire of the buyer will be.

Another consideration that enters into the production problem is the buyer's attitude regarding the used car. It is not likely he will trade unless he can trade at an advantage to himself. The time is coming when average new car sales will be less than 10 per cent. Practically all buyers of cars will be owners of other cars, and every sale will involve a transaction of trade. Dealers in Chicago said their figures indicated the sale of $250,000,000 worth of used cars last year. The actual profit on new cars would not be much more than that. It might be well to study other business lines that have the used product problem, such as typewriters, etc., where the mechanism is good for somebody long after the original purchaser has given it up. There is no separate market for new cars and used cars in the automobile business. If we have too many used cars on hand, the demand for new cars will decrease. We must have a proper proportion.

The great increase in the number of motor vehicles in use greatly increases the service problem and its possibilities. In 1913 there were 1,300,000 motor vehicles; on Jan. 1, 1923, there were 12,500,000. Service facilities must be increased in the next 5 or 6 years, and the problem must be studied from a more definite standpoint. There are approximately 600 models of cars out of production in operation in this Country, and some 400 companies make it their business to supply parts for cars that are not being produced regularly.

It will be found that the retailer tends to develop as the buyer's needs grow, and it is logical, therefore, that we should see, outside of the large cities, a strong development of business among retailers who specialize in the sale of supplies. The business of replacement every year constitutes a large per cent of the total requirement of necessities and parts. The man who wants to grow as a retailer with the business, will have to pay more attention to the replacement end of the business, and the manufacturer will have to give this branch of the industry some consideration also.

Mr. Tipper's address was followed by the complete seven-reel film "Electricity in the Motor Vehicle," produced by the North East Electric Co., showing graphically an outline of the development of electricity and its special use in the automobile.

A MOST IMPORTANT PROBLEM

WE believe that the great problems of highway transportation have received far less attention from automotive engineers than they deserve. Some of the remarks of A. J. Brosseau quoted below from a recent address emphasize this point.

> Transportation is, perhaps, the most vital factor in the lives of all of us. How much attention have you given it in your text-books and in your class-room work?
>
> How do you define transportation?
>
> Are you thinking of it as it was 20 years ago, when the railroad was the only carrier, or do you think of it in terms of the highly complex relationships of today, when we have highway, waterway, electric and steam rail lines, and very soon airways, to be correlated?
>
> Are you dealing with it as it will be in the future, when these agencies may overturn all of our accepted theories of economics, social life and political boundaries?
>
> Have you taken into account the fact that our highway transport has already injected new factors into our economics?
>
> Do you understand the relation between the highway and the vehicle and the important service they render to the public? Do you know that the highway and the vehicle together constitute a great factory, which produces the commodity we call transportation?
>
> Do you realize the importance of these factors in the financial scheme of things, and are you prepared to assist in developing sound theories not alone of finance, but of the actual physical structure of road and vehicle?
>
> Do you know that transportation is today the most important problem confronting the Nation, and, if we are to arrive at sound conclusions, is one that requires the best efforts of the most efficient research men obtainable?
>
> Has it ever occurred to you that the highways are not built for the individual owners, but for the public, and that the privately owned vehicles operating over the roads are in reality mere agencies for the convenience and comfort of this same public?

SULPHATION RATE OF STORAGE-BATTERY PLATES

STORAGE-BATTERIES have recently come into very extensive use particularly in connection with automobiles, and anything dealing with the proper method of caring for such batteries is, therefore, of considerable general interest. The life and efficiency of storage-batteries depend upon the purity of the materials used in constructing the plates and on the purity of the electrolyte. But little exact information is available on the effect of impurities in the solution that serves as the electrolyte, and the methods ordinarily employed for determining the effect of such impurities are time-consuming and often inaccurate.

A new method has been devised by the Bureau of Standards for measuring the rate of sulphation of the plates resulting from local action. This method is rapid and accurate but requires some special apparatus. By this method a study has been made of the rate of sulphation of both positive and negative plates in solutions of varying concentration. This is only the first step in a more extended investigation.

OBITUARY

WILLIAM MACGLASHAN, passenger-car engineer for the Studebaker Corporation of America, Detroit, died at his residence in that city Feb. 22, 1923, aged 46 years. He is survived by his wife and two daughters. He was born July 12, 1876, in Rothsey, Scotland, and received his general and technical education in Glasgow and the West of Scotland Technical College.

His early practical experience between 1894 and 1901 was with several manufacturing companies abroad; but in September, 1901, he became connected with the Winton Co., Cleveland, and continued in its service until March, 1903, at which time he was a designer. Following his European trip in 1903, he was chief draftsman and assistant engineer for the Winton Co. until April, 1912, then becoming chief engineer of the Studebaker Co., at South Bend, Ind., until July, 1913, when he came to Detroit in the interest of the same company. He was elected to Member grade in the Society, Dec. 22, 1913.

Current Standardization Work

ALTHOUGH the secretarial work of the S.A.E. Standards Committee necessitates sending out a large number of questionnaires and reports, a new system of circularization has been instituted which it is hoped will lessen the amount of work required of members in placing data and comments before the proper Divisions of the Standards Committee.

Information has been requested from every passenger-car, motor-truck and engine builder as to the proper individual to receive S.A.E. Standards correspondence. Addressograph plates giving the names and addresses of these individuals will be classified, by the use of a 24-place flag system, so that letters may be sent readily to only the particular companies interested in the subject matter of each letter. Thus it will be possible for a report of the Engine Division, for example, of interest to engine builders to be sent to the proper individuals connected with each engine company and passenger-car and motor-truck builders making their own engines.

As a closer contact will be established, only one follow-up letter will be sent out. This letter will call attention to the original letter and request an answer or acknowledgment. Follow-up letters are sent because it is recognized that frequently it is impossible to answer standards communications immediately and that they are put aside and sometimes overlooked.

In case standards communications on various subjects should be sent to different individuals in one company, the Society should be informed as such a division of correspondence can be taken care of easily.

Status of Important Subjects

The number following each of the subjects listed indicates the number of months its status has remained substantially unchanged. An asterisk means its status has changed during the last month.

AGRICULTURAL POWER EQUIPMENT DIVISION

C. B. Rose, *Chairman*

Tractor Belts and Pulleys (1)—Subdivision report awaiting Division action

Tractor Plowing Speeds (3)—Report to be submitted by O. B. Zimmerman

AXLE AND WHEELS DIVISION

C. C. Carlton, *Chairman*

Differential Gears *—Subdivision report to be submitted by S. O. White

Passenger-Car Front Axle Hubs (1)—Awaiting final Division action

BALL AND ROLLER BEARINGS DIVISION

F. W. Gurney, *Chairman*

Roller Bearings (1)—Subdivision report to be submitted by F. E. Moskovics

ELECTRIC VEHICLE DIVISION

E. L. Clark, *Chairman*

Battery Trays for Electric Trucks *—Awaiting Division action

Lamp Bulbs for Electric Vehicles (9)—Awaiting Division action

ELECTRICAL EQUIPMENT DIVISION

F. W. Andrew, *Chairman*

Magnet Wire (8)—Subdivision report to be submitted by Charles Marcus

ENGINE DIVISION

J. B. Fisher, *Chairman*

Engine Numbers (3)—Awaiting results of tests by Underwriters' Laboratories

Poppet Valves *—Subdivision report to be submitted by W. C. Willard. A progress report is contained elsewhere in this article.

FRAMES DIVISION

W. A. McKinley, *Chairman*

Motor-Truck Frames (5)—Subdivision report to be submitted by W. A. McKinley

IRON AND STEEL DIVISION

F. P. Gilligan, *Chairman*

Sheet Steel (1)—Subdivision report to be submitted by J. M. Watson

LIGHTING DIVISION

W. A. McKay, *Chairman*

Bases, Sockets and Connectors (10)—Subdivision report to be submitted by C. E. Godley

PARTS AND FITTINGS DIVISION

W. C. Keys, *Chairman*

Brake-Linings (23)—Report to be submitted by Subdivision

PASSENGER-CAR DIVISION

R. S. Begg, *Chairman*

Brake-Tests (10)—Report to be submitted by Subdivision

Frame Numbers (3)—Awaiting results of tests by Underwriters' Laboratories

PASSENGER-CAR BODY DIVISION

A. J. Neerken, *Chairman*

Aluminum Molding *—Awaiting report from W. D. Foote

Brass Molding *—Awaiting report from F. G. Smith

Paints, Varnishes and Enamels (2)—Subdivision report to be submitted by C. D. Holley

Steel Molding *—Awaiting report from E. W. Sellstrom

TRANSMISSION DIVISION

A. C. Bryan, *Chairman*

Clutch Standardization (11)—Subdivision report to be submitted by D. E. Gamble

TRUCK DIVISION

A. J. Scaife, *Chairman*

Motor-Truck Cabs (1)—Report awaiting final Division action

Annular Ball Bearings

At the Ball and Roller Bearing Division meeting held in April, 1922, the Division tentatively approved the adoption of the minimum corner-radii specified by the German Standards Committee in place of the radii specified in the present S.A.E. Standards for ball bearings.

Difficulty has since been experienced in changing over production to the corner radii specified by the German Standards Committee. It has developed that the corner radii are too large on most of the small sizes up to about bearing No. 212. There is not sufficient room for the standard rings

and further complications arise in the allowance for grinding. This subject will therefore be reopened at the next meeting of the Division.

Charging-Plugs and Receptacles

The following report on the subject of charging-plugs and receptacles, submitted by J. G. Carroll of the Electric Vehicle Division, will be discussed at the next meeting of the Division.

It is recommended that the following revisions be made in the S.A.E. Standard for Charging-Plugs and Receptacles, p. B38 of the S.A.E. Handbook:

The capacity of the smaller-size charging-plug and receptacle changed from 50 to 100 amp.

Dimension *J* of the smaller size changed from 1⅝ to 1⅛ in.

The note in reference to the capacity changed to read, "The National Board of Fire Underwriters has tested receptacles and plugs of the dimensions and ratings specified with an overload of 50 per cent."

In taking up the question of receptacles and plugs with various truck owners and garage operators, it became evident that there are objections to the use of the smaller size on street trucks on account of the desire for complete interchangeability of various trucks on all charging circuits. The majority of trucks have the larger size and the use of the smaller size tends to increase the difficulty of servicing. It is recommended that this question be referred to the Electric Vehicle Division for further consideration.

E. L. Clark has submitted a report on the standardization of battery trays for underslung compartments.

Lamp Voltage

W. A. Chryst, of the Dayton Engineering Laboratories Co., has raised the question of short life of lamp bulbs. Mr. Chryst's comments are appended hereinafter, together with abstracts of replies received commenting on his letter. The matter has been referred to the Lighting Division for consideration.

The Dayton Engineering Laboratories Co.

We are continually receiving complaints of short life of head-lamp bulbs. Most head-lamp bulbs are marked "6 to 8 volts," which might mean anything. As a matter of fact, in the winter time it is not uncommon for the battery voltage to rise to 8½ or 8¾ and sometimes even to 9 volts, as can be demonstrated readily by mounting a voltmeter on the dash and connecting it to the generator and the battery circuit. The voltage is especially high when the car is not kept in a warm garage.

The trend of legislation is insistence upon lenses and dimming devices to cut down the brilliance of the head-lamps and accordingly it seems that the lamp manufacturers are wrong when they try to get efficiency and high economy from lamp bulbs instead of long life and durability.

Automobile lighting conditions are not in any way parallel to those of commercial lighting, where efficiency and economy are of greatest importance.

W. A. Chryst, Chief Engineer.

Edison Lamp Works

The range of conditions in automobile service is enormous. The lamp manufacturers have carried on very careful voltage surveys covering thousands of cars, batteries and generating systems. In these surveys we have secured data showing the variation of the voltage at the lamp socket with the engine speed for different makes of car, different makes of generating system and cars of various ages of the same make.

We have secured data on the voltage-drop through the switches, the wiring and the sockets; and on the average lamp-load used under various conditions of driving, both city and country, summer and winter, on well lighted and poorly lighted streets and with cars parking; on the average mileage of cars in city and country driving; on the percentage of time the lamps are operated at the various speeds; on the condition of the storage-batteries in service; and on the charging rates of the various generating systems. In addition to this information we have listed the total number of cars of each make in use in the country. From this, the design voltage for various lamps that will give the best all-around average and most economical service to the consumer is figured out.

It would be practically impossible to furnish lamps that would be best for all of the various conditions. If we tried to furnish lamps to meet all of the possible conditions, and the varying characteristics of different makes this would unquestionably result in much inconvenience to the public; in many cases the wrong lamp would be supplied. The net result would be very poor service.

Twenty-one candlepower is required by law in a great many States. It is obvious that obtaining this, together with long lamp-life, would require a low-efficiency lamp that would consume a greater amount of current from the battery than the present lamps consume.

The slight saving in lamp renewals would not begin to offset the trouble and the cost of run-down batteries; we have trouble enough from that during cold weather at present. Also, long-life lamps would be initially so inefficient that at times when the battery voltage was low, their light would be insufficient to meet the legal requirements or to give a satisfactory driving-light.

L. C. Porter, Commercial Engineering Department.

General Motors Research Corporation

I am convinced that much can be done to assist the lighting situation by setting reasonable standards of construction for the lamps and the wiring.

Some lamp-makers are using steel sockets for the lamps, which rust. Steel reflectors are used without flexible connections, with the result that the rusting of the reflector stamping and of the steel clamps holding it give bad ground-connections. I suggest for consideration the possibility of standardizing some of the vital details of lamp construction. I imagine that the lamp-makers would have no objection to having improved standards set, and that the present situation is the result of too much "purchase-department engineering."

J. H. Hunt, Head of the Electrical Division.

Guide Motor Lamp Mfg. Co.

While I have no definite data on the subject, I believe that the higher-priced cars, on which are found the more efficient electrical circuits, have the most trouble with bulbs burning-out. In other words, the car builder who endeavors to decrease the resistance between the battery and the bulb is being penalized for his good intention by the fact that the majority of cars are not built with electric circuits of the same quality. Naturally, the bulb manufacturers make the bulbs to give the best average service, which, of course, is controlled by the medium-priced rather than the higher-priced cars.

C. A. Michel, Chief Engineer.

National Lamp Works

The few cars with which difficulty is experienced are in almost all cases cars in which a special effort has been made to keep the battery fully charged at all

times during the coldest weather, without regard to the service required of the car. In general, the charging rate is set so high that gassing of the battery takes place even with the full lighting-load turned-on. The characteristics of the lead-acid storage-battery are such that the voltage increases gradually until gassing starts, at which time a sharp voltage-rise occurs. Where the normal operating condition of the battery is a gassing one, abnormally high voltages at the lamps can be expected. The effect of gassing on the voltage can be readily demonstrated by cranking the engine with the ignition off for 1 min. on a car showing an extremely high voltage. This will discharge the battery slightly, but enough to eliminate gassing when charging again takes place and it will be found that the voltage at the lamps has dropped considerably.

Lamps are designed for a life materially longer than necessary to meet the average night-operation requirements of the average car for a period of 1 year. Satisfactory candlepower and life undoubtedly are obtained with a large proportion of the cars in service. High-voltage conditions give trouble in some cases but, on the other hand, serious difficulty is experienced in an even larger number of cases through insufficient candlepower. The need for adequate road illumination is expressed in an analysis of accidents by the State of Massachusetts showing that 25 per cent of all night-accidents in that State were due to improper lighting; 7½ per cent resulted from glare, and 17½ per cent were due to insufficient light. Low-candlepower conditions must be given due consideration as they have a most important bearing on the safety of the driver and his passengers. From its very nature, trouble from insufficient light does not present itself nearly as forcibly at a given time as does short lamp-life.

High-voltage difficulties have come up from time to time and in general have been remedied at the service-stations by turning on the maximum lighting-load for 5 or 6 hr. with the engine stopped to discharge the battery partially and also reducing the charging rate to a point where the battery is kept well charged, but below the gassing point when the lights are on. Another remedy that may appeal to the car builders and will give fairly satisfactory results if used intelligently is that of adding an extra point on the switch by which the motorist may insert a low resistance in the lighting circuit at times when the voltage conditions are so high as to cause trouble

The degree of satisfaction resulting with the above-named expedients will depend to a large extent upon the judgment exercised by the motorist. They simply tend to reduce rather than correct the difficulty. The real solution appears to be in the hands of the automobile builders through a decided reduction in the tremendous voltage-range now found in service. Voltage regulators in the battery-generator circuit appear to have possibilities that unfortunately can hardly be taken advantage of in cars already in service. Uniform voltage-conditions, however, cannot be expected unless the regulator is incorporated directly in the lighting circuit.

Aside from voltage regulators there are a number of things that the car builders could do to reduce the voltage range:

(1) Standardize the resistance in all electrical circuits with particular attention to the switches, the sockets, the fuses and their clips, the circuit-breakers, etc. Some idea of the need of such standardization may be gathered from the results of tests on cars equipped with 6 to 8-volt systems in which the voltage-drops from the batteries to the head-lamps varied from 0.21 to 1.43 volts

(2) Provide generators and batteries of sufficient capacity to keep the batteries reasonably well charged under all ordinary temperature conditions

(3) Provide generators with characteristics such that the cut-in occurs at a fairly low car-speed and the maximum charging-current is reached at or below average driving speeds

(4) Replace the dimming resistance in the head-lamp circuits with 2-cp. side or auxiliary lamps to assist in keeping the batteries charged in case the drivers park considerably more than the average time

(5) Issue uniform instructions to service-stations regarding charging adjustments

H. H. MAGDSICK.

White Motor Co.

We believe that the bulb bases, the sockets, the bayonet locks, the connectors and other parts should have not only less electrical resistance but greater mechanical strength.

The bulb failure in automobile lighting, especially on trucks and buses, is, we believe, due primarily to the frail mechanical principles employed in the design. There is not a lamp manufacturer today using good, rigid substantial bulb-sockets or connectors.

A. J. SCAIFE, Chief Factory Service Engineer.

POPPET VALVES

In August 1922 a Subdivision of the Engine Division was appointed to revise and extend the present S.A.E. Standard for Poppet Valves, p. A4 of the S.A.E. HANDBOOK. W. S. Willard was appointed chairman, the other members being J. B. Fisher, of the Waukesha Motor Co., W. H. Spire, of Steel Products Co., and M. W. Wilcox, of the Wilcox Motor Mfg. Co.

A preliminary report was submitted recently for the consideration of the engine builders. If it meets with general approval, it will be transmitted to the engine Division for approval. The preliminary report of the Subdivision follows:

POPPET VALVES WITH CAST IRON HEADS

(1) Poppet-valve sizes, known by the diameter of the ports that they close, shall vary by increments of ⅛ in.

(2) The outside diameter of a valve shall exceed the largest diameter of the cylinder-seat by amounts shown in the accompanying table. The small diameter of the valve-seat shall be less than the port-diameter by 1/32 in.

(3) The over-all length shall be considered as being measured from the top of the valve-seat to the tip of the stem

(4) The position and the length of the valve-stem guide with the valve in its closed position, shall be shown on all valve drawings as indicated in the accompanying illustration

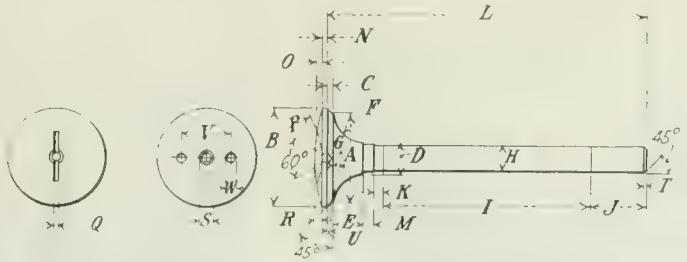
(5) The specified stem-diameter limts shall be measured within this guide position and shall apply to that portion of the stem only

(6) There shall be a chamfer on the tip of valve-stems whose angle shall be 45 deg. with the center-line of the valve and whose width shall be as given in the accompanying table

(7) There shall be a minimum length of unfinished stem-stock projecting below the head of 3/32 in.

(8) There shall be a ground clearance-length between the top of the valve-stem guide position and the unfinished-stem portion of not less than ⅛ in.

(9) There shall be a standard method of inspecting and measuring the truth of the valve-seat with respect to the valve-stem. The method shall consist of rolling the valve in V-blocks placed within the limits of the valve-stem guide position while the valve is held against a fixed stop bearing against the center of the tip of the valve-stem.



DIMENSIONS FOR CAST-IRON-HEAD POPPET-VALVES

Nominal Diameter A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	Drill Diameter W
								Length of Valve-Stem Guide	Position of Guide, Valve Closed	Ground Clearance Above Guide	Valve Length Specified in Even 1/4"	Rough-Stem Length 3/32" Minimum										
1	1 5/32	5/64	11/32	1/4	1/4	7 1/2	0.2470						1/16	1/16	2 3/4	1/16	1/16	3/16	1/32	3/64	1/2	5/64
1 1/8	1 9/32	5/64	11/32	1/4	1/4	7 1/2	0.2470						1/16	1/16	2 3/4	1/16	1/16	3/16	1/32	3/64	1/2	5/64
1 1/4	1 13/32	5/64	7/16	7/16	7/16	7 1/2	0.3095						1/16	1/16	2 3/4	1/16	1/16	3/16	1/32	3/64	1/2	5/64
1 3/8	1 17/32	5/64	7/16	7/16	7/16	7 1/2	0.3095						1/16	3/32	2 3/4	1/16	3/32	3/16	1/32	3/64	3/4	5/32
1 1/2	1 11/16	3/32	17/32	15/32	15/32	7 1/2	0.3720						1/16	3/32	2 3/4	1/16	3/32	3/16	1/32	1/16	3/4	5/32
1 5/8	1 13/16	3/32	17/32	15/32	15/32	7 1/2	0.3720						5/64	3/32	2 3/4	1/16	3/32	3/16	1/32	1/16	3/4	5/32
1 3/4	1 15/16	3/32	17/32	15/32	15/32	7 1/2	0.3720						5/64	7/64	2 3/4	3/32	1/8	3/16	1/32	1/16	3/4	5/32
1 7/8	2 1/16	3/32	17/32	15/32	15/32	7 1/2	0.3720						5/64	7/64	2 3/4	3/32	1/8	3/16	1/32	1/16	3/4	5/32
2	2 1/4	1/8	5/8	5/8	5/8	15	0.4340						3/32	5/64	2 3/4	3/32	1/8	7/32	3/64	3/32	3/4	5/32
2 1/8	2 3/8	1/8	5/8	5/8	5/8	15	0.4340						3/32	5/64	2 3/4	3/32	1/8	7/32	3/64	3/32	3/4	5/32
2 1/4	2 1/2	1/8	5/8	5/8	5/8	15	0.4340						3/32	5/64	2 3/4	3/32	1/8	7/32	3/64	3/32	3/4	5/32
2 3/8	2 5/8	5/32	11/16	13/16	13/16	15	0.4960						3/32	5/64	2 3/4	3/32	1/8	7/32	3/64	3/32	3/4	5/32
2 1/2	2 13/16	5/32	11/16	13/16	13/16	15	0.4960						3/32	5/64	2 3/4	3/32	1/8	7/32	3/64	3/32	1/8	5/32
2 5/8	2 15/16	5/32	11/16	13/16	13/16	15	0.4960						3/32	5/64	2 3/4	3/32	1/8	7/32	3/64	1/8	1	5/32
2 3/4	3 1/16	5/32	7/8	1	1	15	0.6210						3/32	7/64	2 3/4	3/32	1/8	7/32	3/64	1/8	1	5/32
2 7/8	3 3/16	5/32	7/8	1	1	15	0.6210						3/32	5/32	2 3/4	3/32	1/8	7/32	3/64	1/8	1	5/32
3	3 3/8	3/16	1 1/8	1 5/16	1 5/16	22 1/2	0.7450						1/8	3/16	2 3/4	1/8	3/16	1/4	3/32	5/32	1 1/4	3/16

Heads may be crowned or flat; if flat, *G* should be increased by 7½ deg.
Fractional dimensions take ± 0.010-in. limits.
Seat must be true and concentric with stem within 0.003-in. indicator reading by standard method of inspection.
Stem diameters shall be gaged with limit gages.
Stem diameters are based on S. A. E. Steel No. 1020.

The indicator shall bear against the valve-seat and its readings taken while the valve is rotated

(10) The seat angle shall be 45 deg. with the centerline of the valve

(11) Where a slot is used in the valve-head for the purpose of grinding, its dimensions shall be as shown in the accompanying table. Two drilled holes may be used as optional design for this purpose, in which case their dimensions shall be as shown

(12) Valve-stem tips shall be case-hardened before finish-grinding the stem and should show a scleroscope hardness of 45 plus

(13) Valve-stem lengths shall vary by increments of ¼ in.

(14) Fractional dimensions shall be subject to limits of plus and minus 0.010 in.

(15) Valve-stem lengths shall be specified in fractional dimensions

(16) Valve-stem diameters shall take machining limits of plus and minus 0.0005 in., as specified in (5), these limits to be inspected by "snap gages" or equivalent means

(17) Valve-seats must run true with valve-stems as specified in (9), within 0.003-in. indicator reading and shall be free from visible chatters

(18) Valve-head dimensions shall be as specified in the accompanying table

(19) The type of spring-retaining mechanism used shall be optional

Sheet Steel

The Committee on Testing Sheet Steel, which is working under the Sheet Steel Subdivision of the Iron and Steel Division, has held several meetings to formulate methods of testing sheet steel that will be used as a basis for a sheet-steel standard.

Stationary-Engine Belt-Speeds

At the last meeting of the Stationary-Engine Division the work that has been done on the standardization of stationary engine belt-speeds was reviewed and the following recommendation approved as tentative S.A.E. Recommended Practice.

STATIONARY-ENGINE BELT-SPEEDS

Rated Engine Power, Hp.	Belt Speed, Ft. per Min.
1½	600
2	750
3	950
4	1,125
5	1,275
6	1,400
7	1,500
8	1,600
9	1,650
10	1,700
12	1,800
15	1,900

The belt speeds for *portable* engines of 10 hp. and larger shall be 2600 ft. per min., tractor belt-speed standard.
The variation in belt speeds shall not exceed 5 per cent above or below those specified.

March 1923 Issue of Data Sheets

The March 1923 issue of data sheets for the S.A.E. Handbook will be sent to the members early in April. It is important that members using the S.A.E. Handbook in their work should check their Handbooks so that they may be sure that all, as well as the most recent, sheets issued to date have been inserted properly. A check list of all the S.A.E.

HANDBOOK pages and their latest publication dates is given on the first sheet of the March issue of data sheets. These dates should be checked to the dates under the emblems appearing at the bottom of each right-hand data sheet to verify completeness and up-to-dateness.

REPORT ON SEMI-ANNUAL LETTER-BALLOT

The proposed standards and recommended practices printed on p. 529 of the December 1922 issue of THE JOURNAL and approved at the Standards Committee Meeting in New York City on Jan. 9, 1923, were approved by the Society Members in the letter balloting that closed on March 12. The complete vote on all of the recommendations considered is recorded in the accompanying table. The first column gives the number of affirmative votes; the second column the number of negative votes; and the third column the number of Members who do not vote either way.

Subject	*Yes*	*No*	*Not Voting*
Passenger-Car Front-Axle Hubs	152	3	163
Roller Chains and Roller-Chain Sprockets	112	0	206
Electric Vehicle Motors	76	0	242
Generator Flange Mountings	165	0	153
Starting-Motor Flange Mountings (Outboard Type)	162	0	156
Starting-Motor Flange Mountings (Inboard Type)	161	0	157
Starting-Motor Pinions	158	0	160
Magneto Mountings	154	0	164
Spark-Plugs	170	2	146
Flywheel Housings	158	0	160
Running-Board Brackets	135	1	182
Iron and Steel Specifications	193	2	123
Electric Incandescent Lamps	144	2	172
Tail-Lamp Illumination	136	1	181
Crankcase Lubricating Oils	137	9	172
Automobile Nomenclature	188	2	128
Plain Washers	180	0	138
Rod-Ends	176	1	141
Door-Locks and Handles	104	1	213
Wood-Screws	112	1	205
Plate Glass	103	2	213
Gages and Gaging	169	0	149
Ratings of Storage-Batteries for Isolated Electric-Lighting Plants	103	3	212
Storage-Battery Monobloc Containers	103	2	213
Clutch Facings	155	0	163
Vertical Dumping-Hoist Platforms	98	1	220
Three-Joint Propeller-Shafts	117	1	200
Body Hold-Down Clamps	113	2	203

LIVING-WAGE FOR FARMERS

WHEN the industrial worker gets a grasp on the fact that farming as an industry is four times greater than the railroads of America, so far as the capital invested is concerned, his respect for the magnitude of the farming industry is bound to be somewhat increased. In 1921 there were 1,580,000 railroad workers in this Country, as against 10,674,534 employed on farms. The total number of men employed in iron and steel mills and plants making iron and steel products, like machinery and hardware, is but 1,585,712. In short, more than one-fourth the persons engaged in gainful occupations in this Country are on farms.

There are 121,040 industries that depend upon the farmer for their raw materials; they employ 3,074,798 wage-workers, to whom they pay $3,091,157,771 in wages. The output of these industries is valued at $27,560,583,389.

In 1921 the average return of the farmers of the United States for labor, risk and management was $183! At 5 per cent the interest on his investment averaged $610, making a total of $793. But the only figure calling for a comparison with the wages of the industrial worker is $183. In 1921 the average earning of the railroad-shop worker was $1,506, or more than eight times what the average farmer received for his labor. The miner did still better, scoring an average of $1,779. And yet we heard considerable from the railroad-shop worker and the miner about the fact that they were not being paid a "living-wage."

Legislation is needed to remove certain handicaps under which the farmer is laboring, but that will not restore the balance between the farmer's reward and the industrial wage-worker's pay-check. It will merely help a little. The farmer needs all the little helps he can get. And he is in a position to get about what he insists upon in the way of legislation from the present Congress. If legislation could insure his prosperity he soon would be on the high road toward that much to be desired goal.

There is undoubtedly a strong inclination on the part of farmers who intend to continue in production to cut down its volume. What is perhaps more to the point is the fact that thousands upon thousands of farmers have lately deserted farming and sought jobs in industry. The desertion from the ranks of farmers since 1920 has been on a wholesale scale. But even in 1920 there were 1,573,543 fewer people on the farms of this Country than in 1910, in spite of our huge population increase. This process of farm desertion is bound to continue until Europe is again a good and active buyer of American farm products. The thinking farmer has a settled conviction that it will be a long time before Europe will afford him much nourishment as a customer for farm products. He is not counting on that outlet and his mind is decidedly busy with the problems of decreased production. He is inclined to feel that he has been very busy "killing the job," as the union worker puts it, and that it is about time for him to pass up to the industrial worker the same brand of output restriction that the organized worker in industry has been passing to his employer. The farmer is thinking of "slowing down," too. Respecting the readjustments of freight rates, so as to shift some of the burden now resting on raw materials from the farm to the shoulders of fabricated products carrying the cost of industrial labor, the farmer can and will exert a powerful pressure and will probably secure substantial results.

There is one outstanding tendency among all farmers, that of giving less thought to production and more to marketing. They have acquired a stubborn conviction that somehow they will have more to say than heretofore about the prices at which they sell their products. Some have rather wild theories as to how this may be accomplished. But there is a strong mass determination to achieve this end by any and every means possible.—Forrest Crissey in *Journal of the American Bankers Association.*

Applicants *for* Membership

The applications for membership received between Feb. 15 and March 15, 1923, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ADAMS, JAMES R., superintendent of research department and plant metallurgist, Midvale Steel & Ordnance Co., *Philadelphia.*

AITKEN, LEON L., chief tool designer, Fuller & Sons Mfg. Co., *Kalamazoo, Mich.*

ARNOLD, CHARLES F., student, University of Cincinnati, *Cincinnati.*

BALLENTINE, WILLIAM I., vice-president, Advance-Rumely Co., *La Porte, Ind.*

BENDER, E. J., service engineer, Yellow Cab Mfg. Co., *Chicago.*

BLACKMORE, CHARLES C., owner, Charles C. Blackmore Co., *Dayton, Ohio.*

BURKE, EDMUND, salesman and correspondent, Motometer Co., *Long Island City, N. Y.*

CARLSON, CLIFFORD E., student, University of Cincinnati, *Cincinnati.*

CARTER, H. A., vice-president and sales manager, George R. Carter Co., *Connersville, Ind.*

CONNELLY, FRANK HAROLD, student, Tri-State College, *Angola, Ind.*

COOLEY, C. STEWART, student, University of Cincinnati, *Cincinnati.*

CRAVEN, A. R., student, University of Cincinnati, *Cincinnati.*

CUSHMAN, E. H., automotive engineer and assistant manager, Myron D. Kidder, Inc., *Portland, Me.*

DAVIS, M. MOSS, mechanic, Missouri Motor Co., *Columbia, Mo.*

DAY, AUSTIN W., student, University of Cincinnati, *Cincinnati.*

DETTLINGER, FRED. W., laboratory engineer, Plant 5, Studebaker Corporation of America, *Detroit.*

DRESSER, SIDNEY R., cable engineer, Whitney Blake Co., *New York City.*

DUNBAR, FRANK, student, University of Cincinnati, *Cincinnati.*

DURHAM, SAMUEL M., student, University of Cincinnati, *Cincinnati.*

DWIGANS, ROGER W., student, University of Cincinnati, *Cincinnati.*

DWYER, C. EUSTACE, sales engineer, Timken-Detroit Axle Co., *Detroit.*

EARLE, ERNEST A., engineer and designer, Arrow Head Steel Products Co., *Minneapolis.*

EVANS, R. K., sales engineer, Remy Electric Co., *Anderson, Ind.*

FISHLEIGH, CLARENCE T., engineer in charge of experimental engine testing, American Car & Foundry Co., *Chicago.*

FROST, LEON E., student, University of Michigan, *Ann Arbor, Mich.*

GARDNER, F. P., engineer, 111 Broadway, *New York City.*

GARRARD, L. A., research engineer, Standard Oil Co. of New York, *New York City.*

GASSIN, HENRY P., tool designer, International Motor Co., *New Brunswick, N. J.*

GESREGAN, C. WESLEY, sales manager, National Lead Co., *New York City.*

GILLET, CHARLES C., district sales manager, Seamans & Cobb Co., *Detroit.*

GOSS, RICHARD M., student, University of Cincinnati, *Cincinnati.*

GRANER, ADOLF, president, Wisconsin Magneto Co., *Milwaukee.*

GRASS, ALBURN R., student, University of Cincinnati, *Cincinnati.*

GROSS, EDWARD H., sales manager, Donning Carburetor Corporation, *Bridgeport, Conn.*

HAMILTON, GEOFFREY JOHN, student, Cornell University, *Ithaca, N. Y.*

HANFORD, L. T., general sales manager, Paige-Detroit Co., of New York, *New York City.*

HANSELL, HOWARD FOSTER, student, University of Cincinnati, *Cincinnati.*

HAWLEY, FRANK M., engineer, Morse Chain Co., *Detroit.*

HENDERSON, CHARLES E., local purchasing agent, Air Mail Service, *Maywood, Ill.*

HENRY, HOWARD W., chief engineer, Klaxon Co., *Newark, N. J.*

HERSHAM, CONRAD O., tool designer, International Motor Co., *New Brunswick, N. J.*

HODTUM, CLARENCE, student, University of Cincinnati, *Cincinnati.*

HOELSCHER, ROBERT J., student, University of Cincinnati, *Cincinnati.*

HOLLAND, MAURICE, chief of industrial engineering, engineering division, Air Service, McCook Feld, *Dayton, Ohio.*

HOLMES, GEORGE ARTHUR, student, University of Michigan, *Ann Arbor, Mich.*

HUBBARD, GLENN W., engineer, Chalmers plant, Maxwell Motor Corporation, *Detroit.*

HULING, JOSEPH B., foreman, International Harvester Co., *Springfield, Ohio.*

INGALLS, PHINEAS H., student, University of Cincinnati, *Cincinnati.*

KINSEY, KENNETH HARRY, student, Purdue University, *Lafayette, Ind.*

KIRBY, RALPH L., student, University of Cincinnati, *Cincinnati.*

LEAVER, GEORGE ALBERT CHARLES, consulting automotive engineer, A. J. Leaver & G. A. C. Leaver, *Brisbane, Queensland, Australia.*

LUIGGI, MARIO LUIGI, mechanical and civil engineer, American representative of R. Garrett & Sons, Leiston, England, 56 East 87th Street, *New York City.*

LYNCH, W. ROSWELL, sales engineer, Gray & Davis, Inc., *Boston.*

MCARDLE, JAMES P., retail salesman, General Motor Truck Co., *Chicago.*

MANDEVILLE, GEORGE S., JR., student, University of Cincinnati, *Cincinnati.*

MARSHALL, A. F., experimental engineer, R & V Motor Co., *East Moline, Ill.*

MATHER, JUDSON, student, University of Cincinnati, *Cincinnati.*

MONTGOMERY, EDMOND, automobile engineer, Palace Hotel, *Port Chester, N. Y.*

NELSON, CHARLES, JR., draftsman, Western Electric Co., Inc., *Hawthorne, Ill.*

PORTER, R. C., engineer, Stromberg Motor Devices Co., *New York City.*

RAIFSNYDER, F. H., student, Ohio Northern University, *Ada, Ohio.*

RALPH, HORACE F., student, University of Cincinnati, *Cincinnati.*

ROSS, WALTER D., student, Purdue University, *West Lafayette, Ind.*

STEVENS, F. W., associate physicist, Bureau of Standards, *City of Washington.*

SHUSTER, WILBUR W., student, University of Cincinnati, *Cincinnati.*

SMEDLEY, ELMORE H., student, University of Cincinnati, *Cincinnati.*

STOWE, GEORGE, vice-president and general manager, Reo Motor Car Co., *New York City.*

TEACHOUT, J. HOWARD, production manager, White Motor Co., *Cleveland.*

TROUANT, VIRGIL E., engineer, Westinghouse Electric & Mfg. Co., *East Pittsburgh, Pa.*

UPHAM, E. W., chief metallurgist, Maxwell Motor Corporation, *Detroit.*

WARREN, KENNETH WILLIAMS, student, Stevens Institute of Technology, *Hoboken, N. J.*

WEISEL, WILLIS L., student, University of Cincinnati, *Cincinnati.*

WHITE, HENRY J., assistant experimental engineer, International Motor Co., *New York City.*

WILBURN, JOHN PAUL, sales engineer, Prest-O-Lite Co., Inc., *Indianapolis.*

ZEDER, JAMES C., layout work, specification department, Timken Roller Bearing Co., *Canton, Ohio.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Feb. 16 and March 16, 1923. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ALLISON, FRED (M) electrical engineer and superintendent of power, Ford Motor Co., Detroit, (mail) 125 Moss Avenue, *Highland Park, Mich.*

BUTZ, JOSEPH E. (M) research engineer, General Motors Research Corporation, *Dayton, Ohio*

CHERNIACK, NATHAN (J) assistant transportation engineer, Ward Motor Vehicle Co., Mount Vernon, N. Y., (mail) 332 Osborn Street, *Brooklyn, N. Y.*

CLARK WILLARD T. (A) resident partner, Henry W. Peabody & Co., Bartoleme Mitre 1746, *Buenos Aires, Argentina, South America.*

COOKE, B. W. (A) president, Cooke Automobile School and Coyne Trade & Engineering School, 1300 West Harrison Street, *Chicago*

CROWE, G. FRANCIS (E S) student, University of Toronto, *Toronto, Ont., Canada,* (mail) South Residence, University of Toronto.

DAVENPORT, GEORGE R. (M) special engineer, Studebaker Corporation of America, Detroit, (mail) 226 Austin Avenue, *Royal Oak, Mich.*

DAVIDSON, COLEMAN LAWSON (E S) student, Georgia Institute of Technology, *Atlanta, Ga.*, (mail) 53 Cherry Street.

DELANEY, GEORGE A. (A) engineer, Paige-Detroit Motor Car Co., *Detroit.*

DESCHAMPS, ROGER P. (A) manager, Standard Automobile Co., *Brussels, Belgium,* (mail) 102, Chaussee D'Anvers.

DOWNES, GEORGE Q., JR. (E S) student, Ohio State University, *Columbus, Ohio,* (mail) 137 Chittenden Avenue.

DUFFEE, FLOYD W. (A) assistant professor, University of Wisconsin, *Madison, Wis.*

ERNST, OTTO (A) dentist and inventor, 83 Larchmont Avenue, *Larchmont, N. Y.*

EVENBURGH, R. L. (J) 747 Belden Avenue, *Chicago.*

FENN, GEORGE PRENTICE (E S) student, University of Illinois, Urbana, Ill., (mail) 404 East Daniel Street, *Champaign, Ill.*

FIELD, FRANK JAMES (F M) chief engineer, Feroda Ltd., Sovereign Mills, *Chapel-en-le Frith, Derbyshire, England.*

GEISSE, JOHN HARLIN (S M) engineer, Aeromarine Plane & Motor Co., Keyport, N. J., (mail) 3432 Connecticut Avenue, *City of Washington.*

GOODFRIEND, I. F. (E S) student, Columbia University, *New York City,* (mail) Fernald Hall, Columbia University.

GUSTAFSSON, BIRGER G. (A) tool and die designer, Arvac Mfg. Co., *Anderson, Ind.*, (mail) 207 West Ninth Street.

HAUTZENROEDER, RICHARD WAGNER (J) draftsman, Aultman-Taylor Machinery Co., *Mansfield, Ohio,* (mail) 291 West Third Street.

HOLMES, LAWRENCE J. (M) factory manager, International Motor Co., *Allentown, Pa.*, (mail) 128 South 17th Street.

HOLOWAY, PERCIE U. (A) estimator and service salesman, Donovan Motor Car Co., Boston, (mail) 374 Main Street, *Wakefield, Mass.*

HOPKINS, FRED J. (J) designer, International Harvester Co. of America, *Chicago,* (mail) 3402 Flournoy Street.

INGALS, E. FLETCHER, 2ND (J) student, Massachusetts Institute of Technology, *Cambridge, Mass,,* (mail) 1572 Massachusetts Avenue.

IRVIN, W. A. (A) assistant to the vice-president, American Sheet & Tin Plate Co., Frick Building, *Pittsburgh.*

LAUER, CARLETON J. (M) experimental engineer, Doble-Detroit Steam Motors Co., *Detroit,* (mail) 1671 Clairmount Avenue.

LEISTER, FAYETTE (A) sales engineer, Fafnir Bearing Co., New Britain, Conn., (mail) 489 James Street, *Syracuse, N. Y.*

LOCKWOOD, RALPH G. (A) patent lawyer, Lockwood & Lockwood, 1210 Fletchers Savings & Trust Building, *Indianapolis.*

MACLELLAN, W. ADAIR (A) assistant engineer, British Bock Bearings Ltd., 120 Cornwall Street, *Glasgow, Scotland.*

MAHER, GEORGE A. (A) manager, C. M. Hall Lamp Co., *Kenosha, Wis.*

MALCHOW, HENRY J. (A) division engineer, Standard Oil Co., *Milwaukee,* (mail) 1007 First Street.

MARSH, WILLIAM B. (A) superintendent, Locomobile Co. of Illinois, Inc., 515 East 27th Street, *Chicago.*

MEADER, GLENN S. (J) student, University of Minnesota, *Minneapolis,* (mail) 4740 Fremont Ave., South.

METZ, ALBERT G. (A) editor, Chilton Co., 49th and Market Streets, *Philadelphia.*

MIDDLEKAUF, EDISON B. (A) automotive purchasing agent, Texas Co., 90 West Street, *New York City.*

MILWARD, W. F. (F M) chief engineer, W. S. Laycock, Ltd., Millhouses, *Sheffield, England,* (mail) Endcliffe Crescent.

NAFZGER, EDWIN (M) designing engineer, Koppel Industrial Car & Equipment Co., *Koppel, Pa.*, (mail) P. O. Box 222.

NIELSON, MORITZ (M) Phelps Light & Power Co., Rock Island, Ill., (mail) 11536 Normal Avenue, *Chicago.*

PERKINS, ERNEST DELLA (E S) student, University of Michigan, *Ann Arbor, Mich.,* (mail) 603 East Ann Street.

PETERS, JENNINGS D. (J) student, University of Washington, *Seattle, Wash,* (mail) Terry Hall, University of Washington.

PLEISS, PAUL (A) secretary and director, Budd Wheel Co., *Philadelphia.*

RACKMAN, GEORGE JOHN (M) chief engineer, Yellow Coach Mfg. Co., *Chicago,* (mail) 1148 Belden Avenue.

RAGSDALE, EDWARD T. (J) draftsman, Pierce-Arrow Motor Car Co., *Buffalo,* (mail) 40 Custer Street.

RAHUSEN, E. N. (M) manager, Handelsbureau voor Automobiel & Vliegtuig Industrie, 39 Oranjelaan, Ryswyk, Z. H., Holland, (mail) Zella-Mehlis, Szawe Automobile Co., *Thuringia, Germany.*

RANDOLPH, CHARLES L. W. (E S) student, Lewis Institute, Chicago, (mail) c/o C. W. Jarvis, *Courtland, Sacramento Co., Cal*

RAYMOND, ERNEST PETER (E S) student, Tri-State College, *Angola, Ind.*, (mail) 412 West Gilmore Street.

RUFF, ALBERT EDWARD (E S), student, Ohio State University, *Columbus, Ohio,* (mail) 317 West 10th Avenue.

SCHADT, E. K. (M) electrical engineer, Cadillac Motor Car Co., *Detroit,* (mail) 169 Emerson Avenue.

SCHWEIZER, PAUL EUGENE (E S) student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*, (mail) 365 Marion Street.

SMECKEL, ERIC F. (M) assistant chief engineer, Walker Axle Co., Chicago, (mail) 1633 East 67th Street.

SOKAL, EDWARD (M) vice-president and technical manager, Katalite Corporation, 233 Broadway, *New York City.*

SPRING, FRANK S. (M) chief engineer, Courier Motors Corporation, West Monroe Street, *Sandusky, Ohio*

STEVENSON, ROSS J. (E S) student, University of Illinois, *Urbana, Ill,.* (mail) 309 South Coler Avenue.

STOREY, FRANK E. (J) layout man, Maxwell Motor Corporation, *Detroit,* (mail) 3010 Harding Avenue.

TAMPLIN, WILLIAM C. (A) special representative, American Sheet & Tin Plate Co., *Pittsburgh.*

THOMPSON, ROBERT (J) chief draftsman, Ainsworth Mfg. Co., *Detroit,* (mail) 710 Montclair Avenue.

TODD, CHARLES RUSSELL (M) assistant service manager, Olds Motor Works, *Lansing Mich.*, (mail) 1507 South Genesee Drive.

VAUGHAN, HENRY POLK (E S) student, Cornell University, *Ithaca, N. Y.*, (mail) 626 Thurston Avenue.

WEAVER, CAPT. WILLIAM K., JR. (S M) Camp Holabird, Md., (mail) 24 U. S. F. & B Building, *Baltimore, Md.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XII May, 1923 No. 5

Chronicle and Comment

Part II, 1921 Transactions

MEMBERS who have not already ordered Part II of Vol. 16 of the Transactions covering the last six months of 1921 and who desire copies should send in their orders promptly. This volume will, it is expected, go to press the latter part of the month and the printing order will be based on the number of copies ordered by the members. All members who paid dues for the last half of the fiscal year beginning Oct. 1, 1920, are entitled to a copy of this part of the Transactions without extra charge, but copies will be sent only to those members who send in an order promptly. A blank for this purpose will be found in the advertising section on p. 95.

The Summer Meeting

ONLY a few weeks remain before the opening day of the Summer Meeting of the Society. As already announced, this popular event is scheduled to be held June 19 to 23 at Spring Lake, N. J., on the Atlantic coast. Facilities for meetings, recreation and lodging are excellent at this seashore resort; temperatures are sure to be moderate during the meeting period; it is readily accessible by motor or railroad. Reduced fare privileges have been secured from the railroads in the automotive districts; a special through train will carry the Western contingent to the meeting from Detroit, Chicago, Cleveland, Dayton, Toledo and Indianapolis. Reservation blanks, railroad certificates, rate schedules and all particulars will reach the members with a formal announcement about May 5.

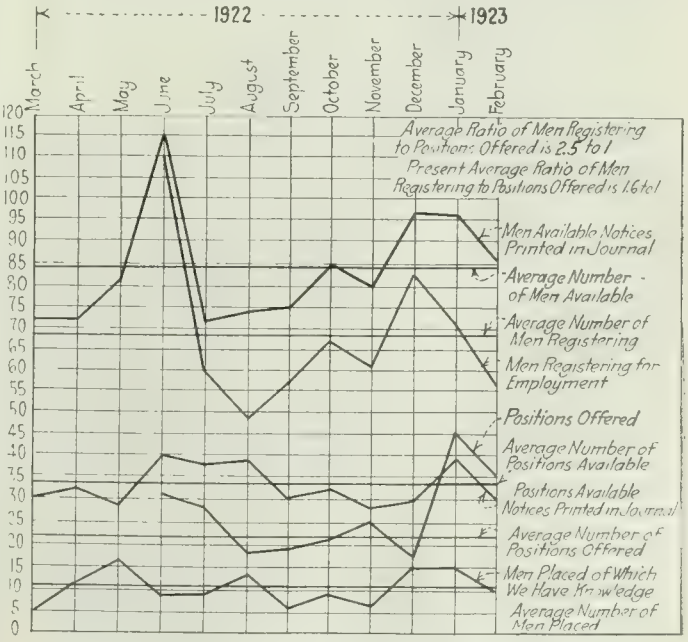
Automotive Transportation

THIS number of THE JOURNAL contains a majority of the papers read at the Transportation Meeting of the Society held in Cleveland last month. An illustrated story of the meeting will be found on page 490. The interest manifested in the papers and discussions at the meeting is clear evidence that we may expect to see more engineering applied to the operation of commercial motor vehicles in the future. Where fleet operation of trucks, motorbuses or taxicabs has been based upon sound engineering principles, the motor vehicle has proved a profitable investment. Slipshod methods whether applied to traffic direction, accounting, maintenance or the selling of transport service, will soon be a thing of the past. Careful study of the papers in this issue gives some indication of what the successful transport engineers are doing; they form the ground work for the accumulation of sound engineering data and experience on the comparatively new science of motor transport engineering.

S. A. E. Employment Service

VERY gratifying results are being obtained by the Society's Employment Service Department through the use of bulletins. The plan has now been in operation for about 1 year. The Society has had listed throughout the year an average of 33 available positions, 41 per cent of which were filled by Society members.

The ratio of men applying for positions to positions offered has averaged, throughout the year, about 2½ men to 1 position, but this ratio has been reduced to



RECORD OF THE S. A. E. EMPLOYMENT SERVICE FOR THE YEAR ENDED MARCH 1, 1923

about 1½ to 1 at the end of February. A marked increase in the number of positions available was noted in January, while at the same time there was a marked decrease in the number of men applying for positions.

The average number of men available throughout the year was 84. Considering that some of these men were holding positions and seeking better connections, and considering the size of the membership, this is a high tribute to the caliber of the men who make up the membership. Employers seeking good men to fill good positions would do well to keep in touch with the Society's Employment Department.

A Market for High-Test Gasoline

THE following data were collected by one of our most active members who was interested in finding out what the average intelligent driver really thinks about good gasoline as indicated by his readiness to pay good money for it. This engineer writes us as follows:

> Last fall one of the large oil companies brought out a fuel that had a specific gravity according to the Baumé scale of from 60 to 62 deg. This fuel was introduced for winter use and we felt it would soon find great favor. On Feb. 1 we began to investigate how well it was introduced among our shop men without any propaganda on our part.
>
> The oil company also markets a winter and summer fuel having a Baumé specific gravity of from 56 to 58 deg. We will call this *B* and the more volatile fuel *A*. We find the following important statistical information which we send to you for we feel that this bears out our contention that the oil companies can profitably and practically market two fuels in the Northern territories where the average temperatures are below 50 deg. fahr. for 6 months in the year.

	Per Cent
Owners in Our Shop Using Fuel *A*	55
Owners in Our Shop Using Fuel *B*	15
Owners in Our Shop Using Other Fuels	30
Owners in Our Shop Using High-Test Fuel	70
Proportion of Ford Cars	51
Ford Cars Using Fuel *A*	53
Average of Cars Used in Winter to Bring Owners to Work	33
Excess of Cars Bringing Owners to Work in the Afternoon Over the Morning	15
Cars Not Used in Winter	6

Contact with Motor-Vehicle Users

A STUDY of the program of papers read at a recent convention of the International Retail Delivery Association reflects great credit on the men who are responsible for the operation of the delivery fleets of our large department-stores. These executives are applying the principles of scientific management to the operation of their vehicles; cut-and-try methods are being superseded by engineering and economic analysis. The designer and the builder of commercial motor-vehicles will do well to turn a watchful eye toward the accomplishments of these men. Unquestionably, they can present ideas to the engineer and the designer.

The following excerpt from a letter received by the Society from the chairman of this convention is interesting:

> After all, the value of automotive engineering can be judged only by the practical daily operations of the men who must maintain the equipment, planned and constructed by the engineers
>
> Our transportation managers and garage superintendents, because of their daily problems in the repair and maintenance of the equipment, find much that they might want to correct in the construction of automobiles, and their advice and suggestions would undoubtedly be of material value to the Society of Automotive Engineers
>
> On the other hand, there are many engineering principles that from an operating standpoint are vital and would be of great benefit in the operation and the maintenance of equipment, if they were presented to our membership from the point of view of the engineer who at the same time has taken the trouble to acquaint himself thoroughly with the problems of the operator
>
> Associations in a given field today cannot work alone and produce the required results. There is a direct relationship among all of them, and better cooperation among such groups will do much to enhance the value of the work of each organization

More was said about this cooperation at the Automotive Transportation Meeting of the Society in Cleveland last month.

Standardization

STANDARDIZATION as applied to manufacturing enterprises may be defined as the reduction of the number of variable factors to a minimum with the object of according to each factor the largest possible share of consideration and capital outlay. In other words, the object is to spread the cost of design, manufacturing facilities and equipment over the greatest possible number of pieces of a given type to reduce the charge on each. A large number of parts can thus be made to carry a heavier charge for better equipment for the purpose of reducing other manufacturing costs, such as time and labor.

It thus becomes apparent that the first matter demanding attention is the nature of and reasons for existing variations in design, with a view to obtaining control of the variable factors. Viewed in this light, many modifications in design and construction appear of the most trivial nature, and certainly should not have sufficient weight to interfere with a general scheme of standardization. Further, in the case of many other changes in design, it will be found that there are no really valid reasons for these at all, the difference being merely due to the fact that designs have originated from various sources.

In the first-named class of differences in design, it is necessary to take a broad view of the whole matter and to consider whether the range of buyers of the product in question is increased or decreased by such departures from a standard. Regarding the second class of differences in design, namely, those which have merely arisen in a haphazard way, as in the case of screw-threads, for instance, the chief difficulty is encountered in the selection of a standard. On this question the preference of the majority is the main guide, and custom becomes the deciding factor.

Another important factor affecting the question of standards is the prevalence of the view that the adoption of standards is a bar to progress. Certainly there are difficulties in the way of making improvements in design go hand-in-hand with standardization, but these difficulties are by no means insuperable. For one thing, a design should not be standardized for production purposes until every measure has been taken to assure that it is the best that can be produced in the light of existing data and practice. Although a standard design is adopted for a period of years, experimental work may still be continued with a view to the standardization of an improved design incorporating the results of research.—*Engineering Production* (London).

Military and Commercial Highway-Transport[1]

By Major Brainerd Taylor[2], U. S. A.

Cleveland Automotive Transportation Meeting Paper *Illustrated with* Drawings

THE paper is a presentation of a practical solution for the coordination of military and commercial transport with rail and water transport. The necessity for combining and coordinating transportation facilities with the idea of organizing a homogeneous transportation network of waterways, railways and highways, proved to be the essence of success in military operations during the World War. The utter inadequacy of pre-war and war-time transport facilities, when organized in separate fields of railroads, maritime shipping and port operations, and the decentralized elements of highway transport, caused the United States Army to make a comprehensive study and plan of the world's war-time transportation with particular attention to the organization of motor transport as the necessary factor in coordinating all transportation facilities. The salient features and general principles of this study and the resultant plan are stated.

The results of this study are applied in an Army plan to coordinate the Nation's network of transportation facilities. The plan is offered by the War Department as a piece of national transportation research influenced by many factors based upon the world's greatest experience in transportation. It contemplates, finally, the establishment in the City of Washington of a National Highway Transport Board or Commission, and of a General Director of Transportation, or a General Traffic Board, to coordinate all transportation facilities.

The principal advantages claimed for this Army plan are the attainment of the full potential capacity of motor transport as a revenue-producing, public-carrier service; the coordination of rail, water and highway transportation so that all three services supplement each other, especially in terminal operations; and a general cooperative action throughout the Nation's commercial, civil and military establishments, to effect the broadest National benefits. It is a general engineering plan leading toward better social and economic conditions and a greatly strengthened national defense.

WORLD WAR MOTOR-TRANSPORT DEVELOPMENT

IN making public Army experiences in transportation and Army recommendations for organizing highway transportation in commerce, the War Department has two interests: First; it is earnestly desired that the Army shall continue to render peace-time service of public value in the industrial life of the Country. Second; the success of all national-defense plans depends very largely upon the capacity and power of our commercial transportation systems, viewed as a national network of coordinated railway, waterway and highway-transport services.

Our greatest national problem in the World War was the "mobilization of man-power and supplies." In this statement "mobilization" must be used in its broadest sense to include all movement throughout the war from points of origin to points of operation. Anything we can gain in normal times toward solving the problem of mobilizing our national resources in time of great disaster will be a big step in preparing for national defense.

The peace-time problem of highway transportation and its relation to railway and waterway transportation has been studied by the Army without any militaristic intention. These studies naturally contemplate the use of highway transport in short hauls of men and supplies to and from railroad stations, steamship docks, camps and Army depots, both in peace-time service and in periods of mobilization. These studies also contemplate questions of public economy, the making, saving or wasting of billions of dollars of private and public moneys due to good or bad transportation practices in our industrial life. The troubles which result from a faulty national system of transportation are of vital import to all citizens of this Country, whether their especial interest be that of capital or labor, of the military or civil, or the one great class to which we all belong, the general public now burdened with increased taxes and a high cost of living.

The first part of this study shows how pre-war transportation, which was developed without any general plan or policy, failed to stand-up under the heavy traffic of war-time movements. It shows how the science of transportation was developed through similar experiences in the different armies of Europe. Those who already know the stories of pre-war and war-time transportation may wish to omit or skip lightly over the first part and give more detailed attention to the second part of this study, which presents a definite, concrete, comprehensive plan for use in solving present and future transportation problems in our own Country.

Pre-War Transportation

Transportation before the war appears to have been developed as follows: Europe, as a result of lessons learned in the Franco-Prussian War, had organized her railroads not only so that they could handle the transportation of commerce but so that they could be operated by their regular civilian personnel, under direction of military authorities in time of war, for the rapid mobilizations and supply that would be required for carrying on military operations. There was also an extensive inland-waterway system in operation on the big rivers and canals of Europe. The British Empire, scattered all over the globe, had forced England to produce her enormous sea power and water transportation. The importance of railroads was not so well appreciated.

Here in the United States, we had built a tremendous mileage of railroad transportation and had produced engines and cars of great tonnage as compared with European railroads. Without doubt, we considered our railroads all that were to be desired from a practical standpoint, and allowed our merchant marine and inland waterways to be nearly starved out of existence. Trac-

[1] Copyright, 1923, by Brainerd Taylor.

[2] Major, Quartermaster Corps, City of Washington.

tion lines flourished in our urban and interurban street-transportation and in European cities, as a very useful hybrid service between railway and highway transportation. Except for passenger cars and the development of roads for touring or military purposes, there was no organized highway transport to speak of anywhere. In Europe, where the value of military highways had long been understood, the roadbeds for highway transportation existed, but no extensively organized highway-transport service had as yet made its appearance.

Speaking of the British people, Col. M. G. Taylor, C.M.G., D.S.O., assistant director of movements, British G. H. Q., is quoted as saying an an address entitled Land Transportation in the Late War[3]:

> The melancholy truth is that in 1914 our ideas of transportation were rudimentary. Our small force of six divisions went to France on their great adventure with no more than a rudimentary organization for transportation. We had an efficient organization for "transport" in the form of road transport, and for sea transport, but we had only a small staff of officers, 31 all told, to insure that our interests were adequately safeguarded in that most important link of all transport services in war, the railways. Coordination between the three, sea, rail and road, was not provided for beyond the provision made in the normal staff organization of the Army, under which the Quartermaster General's branch of the staff is responsible for movement as a whole, and no provision whatever was made for controlling the technical operation of such important points as overseas ports.
>
> What appears now to be a want of foresight cannot be laid to the account of those responsible for directing affairs at the time. The whole of this country was organized, and had been so organized for many years, in separate watertight compartments in regard to transportation. Ports, railways, canals, roads, each undertaking formed an independent organization, the dependency of one upon the others being sufficiently assured by commercial usage. The necessity for any special coordination of the functions of each with those of the others had never arisen because the capabilities of each were equal to the strain imposed by civil movement in peace. It remained for the unprecedented strain imposed by the Great War to bring out clearly that something more was needed if chaos were to be avoided, and that something was the application of the science of transportation. In 1914, military opinion was molded upon civil practice, although the organization put into operation for the movement of our six divisions to France was in effect a fine example of coordinated movement.

This British transportation expert,[3] whom I shall actually quote or follow closely in my thought and in use of phrases during my early remarks on war-time transportation, later says of France:

> It is probable that, in preparing for a future war, France did not have in mind quite so stupendous an affair as that which actually took place, and so for her the ports would not have appeared of so vital a concern as her railways, since most of her supplies would have to be drawn from internal resources. But the point I would like to indicate is that, with all her experience of Continental war, with all the study she had made of probable requirements of modern armies, even France had not realized the need for complete coordination of her transport services, and thus had created a port organization quite independent of her railway control.

In the United States the lack of sea transport, the congestion at our ports and even on our great railway systems is well known. Certain railroads purchased at low prices railroad rolling-stock they did not need, immediately in the early part of the war, while others waited until high prices arrived and then were unable to buy what they needed. Then there was a sudden growth of motor transportation, paralleling some of our biggest railroads, during our own mobilization. These events showed that we had no more general foresight or understanding of how to handle the greatly increased traffic of war than had England and France.

For the allied side, at least, of pre-war transportation, we have the picture of great engineering enterprises, highly developed along lines of rail and water transportation, according to local conditions prevailing in the different countries. Highway transportation as an organized service was non-existent. Specialized transportation, except highway transport, was assuredly developed to a high degree. The science of transportation or logical combination and coordination of the different specialized agencies of transportation, however, does not appear to have been generally understood in any part of the world, unless a study of Germany's transport during mobilization shall reveal a better understanding. For the Allies, the meaning of transportation remained to be developed through evolution in the British, French and American Armies, under the excessive pressure of war-time movements and the forge-like hammering of heavy guns.

War-Time Transportation

It is a well recognized fact that entire nations, not merely armies, fight modern wars. In a war such as we have recently passed through, not only do the resources of a nation have to be mobilized at home but a vast portion has to be further mobilized in international action. Our mobilization during the World War passed over highways, inland waterways and railways at home, then overseas, and finally over railways, inland waterways and highways again in foreign lands. During war, the products of man's industrial work in the fields of agriculture, mines and manufacture, pass through these great processes in movement which he builds up, only to be scattered over other fields, the fields of battle. The channels of these great war-time movements, which we have so lately known, are the same channels through which our future national and international traffic must flow in the more sluggish but ever increasing streams of commerce. One can imagine these channels, in the not distant future, choked again, as in the war, with the great movements required by a reawakened world. Whether that reawakening be for future war or world reconstruction matters not, so far as transportation is concerned. The important thing is to recognize just how our highway transport, for instance, fits in with our national scheme of transportation, and how our national system will operate to advance our interests in world movements.

Visualize in your minds the network of waterways, railways and highways that extended over that part of the world in which the allied nations were active during the war. Inland waterways, roads and highways and the railroads formed interlacing meshes covering extensive areas, while the seaways and many of the long transcontinental railways were like connecting chains, joining up the whole world system.

Again let me quote Colonel Taylor, the assistant director of British movements.[3] In speaking of the war he says:

> I should like to remind you that, while one may consider transportation problems as they arose in any par-

[3] See *Journal of the Royal United Service Institution* (London), November, 1921, p. 699

> ticular theater, the fact must never be ignored that these problems were, as a rule, merely manifestations of causes which arose at places possibly remote from the theater in question. Transportation in any area is, in other words, merely a link in a chain, or rather a small area in a network, of processes which proceed simultaneously in many widely separated parts of the world. Any disturbing cause in one part of this network is bound to have its repercussion in the particular locality under consideration, and the delicacy of the machinery involved is such that a slight maladjustment in one process may have a considerable and even a disproportionate effect for evil in the supply of an army. Perhaps you may incline to the view that I labor this point unduly, but I cannot help feeling that when it is possible to study the Great War as a whole, and as a matter of history, it will be found that many of our earlier troubles in the struggle were due to an imperfect grasp of this truth. Transportation was the cause of our great difficulties; not fighting power, leadership, or the more active side of military training.

If this commentary is true, and it is certainly corroborated by our own experience, then a nation's best safeguard and most practical method of preparing for national defense lies in the development of her national system of transportation. Rapid mobilization, well regulated supply, quick maneuvers in combat, all most vital factors in warfare, are dependent upon the capacity of the whole network of transportation for making effective coordinated movements rather than upon the number of railroads, ships or trucks which a nation may possess. In commerce, rapid collection and delivery of passengers and freight, regulation of supply and demand, quick movements in relation to collection of peak loads and distribution to markets mean exactly the same things. Transportation is blind as to peace and war. It is a matter of making and coordinating movements regardless of what movements are for.

After the strain of early mobilization and the sudden expansion of the French motor-transport, which resulted in the successful turning movement that stopped the German advance on Paris in 1914, allied transportation, still of a pre-war character, seemed to operate smoothly enough during the long period of stationary warfare which followed the first battle of Ypres. With the Somme offensive, however, in 1916, the weak points in the Allies' transportation showed up. At first there was a lack of trucks at loading points. Next railroad trains had to be strictly limited in number below the capacity of trunk lines, because of lack of engine power, lack of drivers and lack of coal. "Then came a reduction in the capacity of the lines themselves, because the shortage of maintenance labor and material made it impossible to keep them in condition." In short, the railroad service in France began breaking down. One trouble bore heavily upon another with the effect of beating back the movement of the whole system upon itself.

The ports were independent of the railways. The latter failed to clear away the imports, yet imports came in in ever-increasing quantities, in satisfaction of the requirements of the troops in operations, which were planned on a generous scale. Consequently ports, transit sheds, quays and wharves became congested with material of all sorts. Stores could not be moved because they became buried beneath mountains of other stores not yet required forward. Gradually, movement as a whole slowed down, and complete cessation was threatened. As Colonel Taylor says:[4]

> At the same time our Allies became seriously alarmed at the state of affairs developing behind their own armies in a manner exactly similar to what we were experiencing. They were dependent upon imports to a far greater extent than they had originally contemplated, owing to the great excess of demand over the productive capacity of the country made by modern methods of warfare. Consequently, the imminent breakdown of the railways of France was not a local affair threatening one army alone, it was universal, a matter of miscalculation of capacity or of faulty organization. For the French it was the former; for us, as we began to think, the latter.

This state of affairs was followed by the importation from England into France of trucks, engines, railway men and fuel. England also sent over a man of experience and reputation to set British transportation to rights, to connect-up ships, ports, railways and roads, and to put the whole affair on a working basis. This all happened during the battle of the Somme, up to that time the greatest battle ever fought; it happened at a time when the Allies were committed to action and could not back out without the most serious consequences. This British writer[4] laments: "The truth cannot be evaded that it could all have been foreseen and corrective measures taken before the battle, had the science of transportation and its practicable application to war been studied earlier."

Sir Eric Geddes was the man sent over to France by England to solve the new transportation problem. He saw what was wrong and devised the full organization for transportation which was required. He linked-up ports to railways, railways to roads and inland waterways to both. He secured the regulation of sea transport with direct reference to port capacities and to the possibilities of clearance from the ports inland. He developed ports, railways and roads by construction until they could reasonably be expected to carry out the work required of them, and he brought the whole under one unified control responsible for coordination of effort. He showed what *transportation* meant, and how each variation in one process of movement must inevitably have its effect on the others. He finally became Director-General of Transportation, took command of the new organization, got it into running order, and controlled its operation until it found its own feet. With the exception of the German spring offensive in 1918, this was the biggest crisis of the war, and realization of the importance of combining and coordinating sea, rail and highway transportation was, without a doubt, one of its chief and most far-reaching results.

There were many transportation crises between 1916 and the end of the war in 1918, that caused many anxious periods. Many of these we, the United States, shared with our Allies. With the breaking down of the railroads, motor transportation sprang into great prominence. So long as the railroads operated satisfactorily, the motor transport which had been provided and maintained in France was amply sufficient, if it was not called upon to undertake an undue proportion of long-distance work to relieve railways. As a natural result, however, of the railroad breakdown, motor transport, even for really long distances, began to be regard as the most reliable form of overland transport.

The British admit that their motor transport was therefore greatly overworked, and it gradually deteriorated. This deterioration, so far as the vehicles were concerned, was not very marked in the early stages and, in 1916, and early 1917, the course of events was not very obvious, except to the directors of motor transport

[4] See *Journal of the Royal United Service Institution* (London). November, 1921, p. 699.

who were responsible for the provision and upkeep of the vehicles. The result, which *was* clearly obvious, was the effect on the roads due to the heavy use of motor vehicles. The provision of stone for repair became a serious factor of rail transportation. To a certain degree the increased use of road transport, due to the lack of railway facilities, was thus responsible for an increased *use* of the railways; it therefore partially defeated its own object of relieving the railways.

The alarm caused by the deterioration of the vehicles and the roads had its effect in promoting the use of light railways. These saved the wear and tear on both motor trucks and roads. About the time this system of transportation got fairly well going, the Germans demonstrated how easy it was to cut light railway lines with shell fire, and then shoot to pieces the rolling stock and supplies that became stalled. Inasmuch as motor trucks could manage to go around shell holes and keep moving, unless actually hit, motor transportation proved to be much less vulnerable than railway transport. The policy of transportation therefore turned back toward standard-gage railroads, with supplementing road transport, in forward areas. Light railways were to be used as much as possible in unexposed positions, to save wear and tear on roads and motor vehicles.

In 1918 the French railroads had been brought back to life, but British motor transport, in consequence of overuse, was going from bad to worse. Due also to German submarine activities, the gasoline supply was threatened sufficiently to cause added anxiety and need for economy.

In the British Army, as later practised in the American Army, motor vehicles, instead of a motor-transport service, had been furnished to small organizations. These adverse conditions, however, forced the withdrawal of every motor-transport vehicle that could be spared from military units for reconditioning, and their further use after reconditioning in what the British called "general-purpose companies" which were assigned to a "general headquarters, motor-transport reserve," for centralized control. This was the beginning of the development of a British highway-transport service, as opposed to a service organized simply to supply and maintain motor vehicles. The motor truck started off on the wrong foot in all countries following the lead of its elder brother, the so-called "pleasure" car, which is essentially an article of supply furnished to individuals primarily for their pleasure. Effective movements and economy in supply and maintenance ordinarily are secondary matters with such cars, but they are vitally important with trucks and other motor-transport vehicles operating in a public or commercial service. Vehicles of the passenger-car type used in a public service or in commerce are *not* pleasure cars, and the operation of so-called pleasure cars, as such, should never be confused with that of motor or highway transport. They should be termed "passenger cars."

These British general-purpose motor-transport companies were allotted, as in the French army, by G. H. Q. (General Headquarters), to formations which required them, but only for so long as they were actually required. Decentralization and loss of control were not permitted. There is indicated in this British action recognition of a basic principle in highway transportation. Control over the operation of motor transport must be centralized under the same executive authority that dictates the means of maintaining the vehicle equipment at all times in a reliably serviceable condition, with reasonable economy. I shall refer later to a similar, though arrested, movement in our own Army, and again I shall recommend this principle as one of great importance in the development of commercial highway-transportation as an integral factor in general transportation.

Military highway-transportation became a matter of building up a motor-transport service to handle general road movements, under centralized control, rather than a service for supplying and maintaining motor vehicles which were issued to supply and combat organizations for them to operate exclusively in making their own movements.

It is interesting to note that the British entered the 1918 campaign that ended the war on a policy of coordinating sea, rail and highway transportation. Due to forming a general motor-transport service, they made an immediate saving of 4000 motor-truck drivers who were thus released for fighting. They also made rapid progress in reconditioning their deteriorated roads and motor vehicles. The Assistant Director of British Movement, in referring to this policy of coordinating land transportation, says, "Thanks to the policy adopted, we were able to draw the fullest advantage from our road transport."

The French had already a well organized and smoothly running Motor-Transport Service which was centrally controlled and dispatched for general road movements. It was coordinated with railroad movements. In the French Army, the operation of motor transport reached the highest degree of efficiency. The highways which were organized for motor-transport movements of personnel and materiel which were made over them reached enormous proportions. The French railway system and the French highway system were separately organized, but operated as a coordinated whole.

In May, 1918, as a result of the final effort of the German Armies to capture Paris, French railroads were again so disorganized as to be rapidly approaching a state in which they could be disregarded as a factor in the military situation for large movements. It was only the work of the road-transport service which enabled the allied force to be maintained. Had the policy of supplying motor vehicles to field units not changed in the French and British Armies to a policy of supplying organized highway transportation, the German spring offensive would have encountered the same weakness of movement behind the allied lines that existed during the allied Somme offensive. Being on the offensive, however, in 1918 she must surely have felt any such great weakness in transportation as that of 1916, and pressed the harder for a final decision. Highly organized highway transport in the French and British Armies was the principal agency of movement that enabled the Allies to stop the German drive in 1918, just as the crudely organized motor transport in the French Army enabled the Allies to stop a similar German drive in 1914. The repeated imminence of world disaster, due to faulty transportation policies, in 1914, 1916 and 1918, is only too apparent.

It would be useless to review war-time transportation with the idea of using its lessons profitably in any post-war reorganization or establishment of national policies, without facing our errors with honesty and boldness. Every foreign government knows that, in 1916, the United States was disgracefully unprepared for even any effective defense in its homeland against the attack of any first-class power. It also knows that, in spite of this unpreparedness, with French and British help and protection, the United States mobilized its resources and arrived in France with sufficient dispatch and force to

turn the rising tide of defeat away from her Allies. With the exception of our national unpreparedness we have proud records as a Nation, as an Army, as minor organizations and as individuals. At home and overseas, we bent our energies together to win the war. With such facts behind us, it seems to me that we can and should focus the light of research upon our errors. The groups or individuals who were personally responsible for errors have unusual opportunity to render constructive services of unlimited value by admission and discussion.

In the spring of 1918, we in the American Army were supplying vehicles to all forward units in very much larger numbers and truck-ton capacity than the French and British had done. Notwithstanding this, we were also receiving assistance from the organized highway-transport service of the French to move our troops and their supplies in battle maneuvers. Although our vehicles were all practically new, rapid deterioration began to cause serious anxiety. Every small organization in the field, equipped with motor vehicles, began tearing down its disabled vehicles to make its own repairs. Repair parks with field units were littered with dismantled vehicles. There was no systematic connection between these combat and supply organizations and the motor-transport service organized and equipped for general repair. Out of every two or three motor vehicles requiring general repair, they would tear down all and then rebuild one, scrapping what was left; this, mind you, in the first year of service of brand-new vehicles. It was justified, they thought, by the exigencies of military service.

To maintain their own small fleets in readiness for field movements they knew would come, each small combat organization and decentralized truck-train started in to rob disabled vehicles, wherever they were found, of the spare parts of which they could be dismantled. These parts, with the supplies they requisitioned from automotive depots before they were needed, they hoarded against the day when their own vehicles would need repair. Every truck driver in the Army became a collector and a road vulture so far as disabled trucks were concerned. Small-fleet operators cannot be blamed for these uneconomical practices. They were incident to a system of decentralized trucking.

The Motor-Transport Service, organized only for automotive supply and repair, was bitterly assailed for not having the spare parts required by hard-pressed forward-units under these conditions. The Motor-Transport Service gave up all the supplies it had, required by such units, and then was unable to make the repairs for which it was responsible when the dismantled and stripped vehicles finally drifted back to repair parks.

The weakness of decentralized control in motor transportation was not lost upon General Pershing and his staff. After our St. Mihiel drive, and during the Argonne, in October and November, 1918, General Staff officers from our own G. H. Q. were working in the First and Second Armies, drawing out about 60 per cent of all divisional motor-vehicle equipment to form a general-service motor-transport reserve to be placed under the control of Army commanders. This would have been similar to reforms in motor transportation undertaken earlier in 1918 by the British, and already effective with the French. With the signing of the Armistice and cessation of pressing need, this movement was abandoned, before our fighting troops and supply services could experience the same benefits from the change the French and British had experienced. I have always looked upon this arrested centralization as a great misfortune, the loss of a wonderful opportunity for our Country to experience the power and capacity of an organized Motor-Transport Service as against the use of small fleets and single vehicles. We did make the change from the decentralized operation of motor vehicles to the centralized system exactly as the French and British had done, in the American Service of Supply.

Without knowing at the time that we were going through the same phases of motor-transport development that the French and British had gone through, we made our changes to meet the requirements of new emergencies as they arose, when old methods failed. Perhaps the personal touch of my own observations and experiences in the Advance Section, A. E. F., may serve to bring out the fact that we Americans were having the same experience as our Allies in the evolution of transportation that was going on everywhere during the war.

Early in January, 1918, I was appointed Chief Motor-Transport Officer for this Advance Section, from which point of vantage I had a wonderful opportunity to observe the operation of motor transportation; first in the Supply Services, A. E. F., and in the separate Divisions as they arrived, then in the First and Second Armies from their formation after Chateau Thierry to the Armistice, and finally in the Third Army during its advance, without railroad service, to Coblenz on the Rhine. I also observed part of the French Motor-Transport Service and caught glimpses now and then of some of the British and German motor transport. With all this transportation operating about me, I was busy organizing the American Motor-Transport Service in the Advance Section. Indeed, most of the vehicles issued to the armies in our front, and all the automotive supplies, were received from the base and intermediate section and distributed from Advance Section parks and depots. In addition to supplying combat and supply units with the vehicles and the spare parts they required, we were establishing the advance automotive-supply depots and repair shops to make the major and general repairs that would be required by about 100,000 motor vehicles operating in the forward zones.

In the Motor-Transport Service which I personally commanded, there were, roughly, 10,000 officers and men, many of them highly experienced in one phase or another of the automotive industry. We coordinated my knowledge of the Army, and that of the three or four regular officers who served with us from time to time, with their combined knowledge of the industry, to build up our service to meet the motor-transport requirements of the war as it developed in our vicinity. While these temporary officers and soldiers were learning to look at motor transportation from a military point of view, they were teaching the regular Army the details of motor-truck operation and repair. Together, we learned about the science of transportation or the science of movements. The military mission in which we were using this science was a temporary situation, an incident in the history of transportation.

The weakness of decentralized motor-transport organization in a crisis is illustrated by the following incident in our Advance-Section experience: The general order issued from G. H. Q. in December, 1917, which created and described the Motor-Transport Service in the A. E. F., distinctly states that a Motor-Transport officer is *not* responsible for the operation of motor vehicles after they are issued to units and other services. Certainly the chiefs of other services took this view. During a serious

emergency, when it was perfectly apparent that some one Motor-Transport officer had to act to direct road movements over the entire Advance Section, I was forced to assume this responsibility over all motor vehicles in the section. Although not recognized by official orders, this action was, nevertheless, generally recognized as the correct solution of the particular problem in transportation presented by the emergency.

On May 30, 1918, during the height of the German drive toward Paris, our American G. H. Q., with considerable evidence of anxiety, directed me, as the Advance Section Commander's Motor-Transport Officer, to make certain road movements involving the use of several hundred motor trucks. Having very few trucks left under me, as a result of the above quoted order, and realizing that the order carried with it the expectation that I would meet and overcome whatever obstacles were in the way of its execution, I assumed command over all motor vehicles in the section, regardless of what other services they might belong to, and sent out telegrams, dispatch riders and officers on motorcycles to gain actual control. About 300 vehicles were dispatched to threatened points within a few hours and as many more mobilized for further orders from G. H. Q.

On May 31, the Commanding General issued orders that, except in a few instances where the vital importance of a local activity made it inadvisable to ride roughshod over its commander's objections to giving up his fleet, all motor vehicles would be turned over to the Motor-Transport Officer for operation. In accordance with this order, vehicles and small fleets were actually pooled for general transportation at motor-transport centers established with relation to rail-heads, railway stops, camps, depots and other activities, and the control over motor transportation and maintenance of vehicles was centralized in my office.

As the effectiveness of this centralized motor-transport service became more and more apparent, even the exempted vehicles and fleets were turned over to us by the voluntary action of their local commanders, with only one noticeable exception, which no doubt would have followed had the war continued. The combined fleet, which was finally maintained and operated from these centers under my general direction, numbered about 3500 vehicles of all kinds. In the St. Mihiel and Argonne offensives, this fleet not only carried on the increased highway-transport service caused by these drives, without help from outside sources, but it gave up to the combat divisions about 15 per cent of its vehicle equipment and many of its officers and men. Increased effectiveness and economy in motor vehicles and maintenance of vehicles were very apparent after centralization.

This incident showed officers at G. H. Q. that they could not expect action in road transportation if they had to wait for orders of movement to be given to from 30 to 40 or more scattered fleet operators. It showed the Commanding General of the Advance Section that he could not meet his responsibilities for making quick or effective road movements unless he centralized control over his motor vehicles in a single office, vested with authority and equipped with communications to carry out his orders of movement. It showed us in the Motor-Transport Service that unless we hooked up the function of operating vehicles with the function of maintaining them in a systematic manner, there would be, in a comparatively short time, no movements whatever to speak of, with the rapidly deteriorating trucks and cars with which we stumbled through that emergency. It showed us that anything but a well balanced, centrally controlled Motor-Transport Service is dreadfully wasteful and extravagant, and that decentralized trucking will always be ruinous to many private operators and extremely dangerous to any important enterprise which relies upon it.

Experiences similar to these, but perhaps less emphasized, are being encountered in commercial transportation at present. We progress in circles; war transport follows commercial transport which, in turn, follows war transport again. It is a vicious circle when we pass on bad practices or fail to translate the teachings of one experience to the next. On the other hand, brilliant success in the movements of war and commerce should follow a nation's intelligent appreciation and application of the science of transportation which it develops in its combined experiences.

See how closely we followed our pre-war commercial experience in the use of motor vehicles. During the period from January to May, 1918, every officer of importance and prominence and many an officer who was not prominent at all, except for his continual joy-riding presence on the highway in a high-powered car, thought he had to operate or control his own motor car. This idea, that each officer must have his own car, is directly traceable to our "pleasure-car" experience at home. The idea that each individual citizen of this Country should own and operate his own automobile is the secret of the wonderful rise of our automotive industry. It is the reason for the fact that, in a world registration of cars and trucks,[5] more than 12,364,000 of the world's 14,750,000 motor vehicles are in the United States. Of these 12,364,000 motor vehicles, more than 11,000,000 are motor cars and motorcycles. In the use of motor cars, individual pleasure, personal comfort and satisfaction are the primary considerations, even when business and business efficiency are claimed as the real reasons for obtaining a motor car. Effective transportation with economy in vehicle operation and upkeep is a secondary matter, in the case of passenger-car types used by individuals. This is so in civil life; so it was in the Army, among regular and temporary officers alike.

Again note the influence of pre-war commercial practice on military transport. Every small organization in our Army was issued animal-drawn and motor-drawn vehicles according to the weight and cubic measurement of its impedimenta, and the ammunition, food and other supplies required for its independent road movements and action for a given number of days. These vehicles were controlled solely by immediate commanders who had no power to control general traffic, except to gum it up, and no practical knowledge or means of keeping their vehicles in a constant state of mechanical efficiency, with economy in use and repair. This was absolutely the replica of commercial practice in the trucking game. Here in the United States, the 1,364,000 or more trucks which have been built so far are held in comparatively small fleets by companies that cannot afford to combine in their private trucking services adequate means for complete maintenance, which alone is capable of reducing the costs of vehicle operations and upkeep to its most effective and most economical basis.

The number of small, private fleet-owners who have operated trucks without realizing potential profits, and even at a loss, is better known in the automobile industry than anywhere else. There have been some interesting data furnished on this subject by the Curtis Publishing Co. and other sources. Accurate cost accounting

[5] See *Automotive Industries*, Feb. 22, 1923, p. 366.

in trucking has not been practised much more in commerce than it was in the Army during the war. Very few companies, I venture to say, know exactly how their operating and maintenance costs compare with what their vehicle equipment should cost to operate and maintain, or whether revenues realized with new vehicles will continue as the vehicles deteriorate. There is no possible way to obtain comprehensive and reliable cost accounts from a decentralized system of trucking. As to the exercise of highway-traffic control and the coordination of highway-transport movements with rail and water movements in accordance with a regulated supply and demand, no such thing was practised in commercial trucking and therefore none was practised in the Army. The problem of highway-traffic control is bound, in the near future, to become fully as interesting and urgent in commerce as it was in the hectic movements of war; that is, if the production of passenger cars and the construction of highways are any indication of what the next 5 years will bring forth in the way of cargo-carrying trucks and tractors.

In dealing with the growing use of motor trucks in American commerce and their relation to the railways, in which the Country has vital interests of a financial and a practical nature, transportation engineers are face to face with the same questions that were faced in wartime transportation. Some of them are the same engineers who wrote into our military laws the conception and vision which in 1917 and 1918, only about 5 years ago, they had concerning motor transportation. It will be very interesting to see whether their vision and understanding concerning motor transportation have developed at all since then, and how they have developed. In December, 1917, one of our pioneer motor-transport officers submitted to G. H. Q. a draft of the order that created the Motor-Transport Service. An engineer on the General Staff, who now holds an important position as a consulting engineer in general commercial transportation, revised and edited this draft and wrote into the order the following vision of motor transportation. His conception became military law when signed by the Chief of Staff, who needs must rely upon the judgment of his engineers in such matters. The order states

> The Motor-Transport Service has no responsibility in connection with the *operation* of authorized M. T. S. vehicles and units after their assignment by competent orders to units or to other services. All movements of transport so assigned are controlled directly by appropriate commanders. . . . The principles enunciated in (*f*) (this refers to sentences just read), are further emphasized by the following simile: An authorized automobile or automobile unit, after assignment to an organization, is exactly on the basis of a horse, mule or field train assigned to a regiment, and therefore the authority of the M. T. S. over the vehicle or unit so attached does not exceed the corresponding authority of the remount or other service over the animals, vehicles and transport units similarly assigned.

This idea that an automobile took the place of an officer's charger and that a truck took the place of the old Army mule is stamped indelibly upon the minds of many Army officers. It also prevails outside of the Army, where the family phaeton and "Old Dobbin" have given place to phaeton and sedan motor cars. The rich man's coach is replaced by his limousine. Every conceivable kind of a mule or horse-drawn cart or wagon has been replaced by a similar motor-driven vehicle under the same kind of decentralized ownership as in the case of its animal-drawn predecessor.

Individually operated vehicles and small fleets can never give an effective and economical highway-transport service in commerce, any more than they did in the war. Already they are combining into larger services. Witness the taxicab companies, the American Railway Express Co., and others. These are steps in the right direction, but we need to speed up the process. Transportation requires larger trucking companies in closer combination with railways and waterways.

Shortly after the issue of the December, 1917, order, which damned the motor truck as a muleish thing and the Motor-Transport Service as nothing more than a hospital service for trucks, the author of that limited idea moved out of the sphere of direct influence on military motor transportation. An order was then issued from G. H. Q. which created the Motor-Transport Corps in the A. E. F. This order showed greater vision and a growing understanding in that it gave this specialized corps, equipped to operate motor vehicles, operating control over some of the motor vehicles in the A. E. F. It provided for the organization of motor-transport units for general trucking purposes. The majority of motor vehicles were issued to other services, however, and therefore exempted from being included in the organization of a Motor-Transport Service.

Although the order of May, 1918, was a great step forward over the order of December, 1917, the substitute of a truck for a mule idea which had been given the Army interfered with all subsequent efforts to centralize and coordinate motor transportation. Even under the May order, no one authority could be held responsible for conducting satisfactory road movements. Always, although we had more trucks than the French, we had to have help from them in moving our troops in battle. We were not experiencing a saving of 4000 truck drivers and "drawing the fullest advantage from our road transport" which followed the British centralization of control over motor trucks.

Highway-traffic control, at this period, was looked upon as a matter of giving orders to combat and supply organizations to make road movements, and then of giving further orders to military police to stand at the crossroads like traffic officers in America to keep the vehicles moving. The railroad idea of traffic control, with its comprehensive inclusion of coordinated movements of passengers and freight, made by an operating service and supported by organized maintenance of way and equipment, came very slowly. The still more advanced idea of general traffic control, that is, controlling and coordinating the required movements of passenger traffic and freight traffic through terminals and ports, over railways, waterways and highways, each service made up of its own specialized branches of Operation and of Maintenance, was not to be expected until the threat of impending disaster to most important missions became a compelling factor in the general situation. It would require a very large book to hold all there is to tell about the evils of decentralized motor transportation, and of failure to realize the necessity of coordination and continuity of movements throughout the network of general transportation.

As an example of the result of broken continuity in general transportation, I will refer to the report of E. A. Halblieb and J. W. Tracey, who were sent to Europe by Dodge Bros. in the fall of 1918. Dodge cars were facing a general breakdown, although the Dodge company had supplied all the spare parts requisitioned. We had mountains of Dodge parts in the Advance Section, but certain vital parts, required in extraordinary quantities as a result of the unforeseen and excessive demands of the

decentralized trucking system in the armies, were not in France. Other makes of vehicle were also approaching a general breakdown and need of overhaul. With a breakdown in our motor transport, unless French and British transport could have been substituted, the American offensive, then rolling back the Hindenburg line, would have been halted. Forward units could not have advanced, rail-heads and dumps could not have been cleared, rail trunk-lines and ports would have been hopelessly congested, rail movements at home and overseas shipments, expanded to support our offensive campaign, would have further flooded the already congested ports. The whole general system of overseas movements was threatened by the spare-parts situation in motor transportation.

Had the war and our decentralized system of trucking continued a few weeks longer, we would, I am confident, have encountered this very serious situation. It would have been similar to the British experience during the Somme offensive in 1916, and the work of coordinating our overseas movements, the greatest transportation undertaking the world has ever seen, would have been harder and would have taken longer than it did with the British, because of the greater distances and difficulties of communication. The British transportation expert, whom I quoted earlier in my paper[6] might have been writing of the American transportation situation when he said:

> While one may consider transportation problems as they arose in any particular theater, the fact must never be ignored that these problems were, as a rule, merely manifestations of causes which arose at places possibly remote from the theater in question. Transportation in any area is, in other words, merely a link in a chain, or rather a small area in a network, of processes which proceed simultaneously in many widely separated parts of the world. Any disturbing cause in one part of this network is bound to have its repercussion in the particular locality under consideration, and the delicacy of the machinery involved is such that a slight maladjustment in one process may have a considerable and even a disproportionate effect for evil in the supply of an army.

In looking toward the future of motor trucking and in adopting a national policy of transportation, this established truth should not be overlooked. It is not only essential to preserve this broad vision of world transportation in formulating national policies, it is also necessary for the automobile industry, the railroads and the truckers to build in harmony with it, if they wish to build on solid foundations that will withstand the strains of increased movements due to war or national expansion.

Post-War Transportation

I have barely touched upon pre-war transportation, but enough to show that it was one of uneven and uncoordinated development of specialized services. Sea transport dominated in Great Britain, railroad transport dominated in Europe and the United States. Canal and river transport flourished in Europe until interrupted by the war. Highway transport was everywhere a matter of supplying and operating individual vehicles, or small independent fleets.

I have shown more at length the evolution of transportation throughout the war, the similar experiences of the French, British and American Armies with regard to motor transportation and its development as an organized service for general purposes. I have indicated the development of coordinated waterway, railway and highway transportation as a result of war-time traffic, with its probable effect upon the world's history in the part it played during the Somme offensive and the drives of 1918.

We have done with war, so far as this generation is concerned, I hope. So far as future wars are concerned, our armies will enter them with whatever transportation practices are general in commerce at the time. We cannot afford to create a national transportation system for war alone. Ideas of special preparedness measures in transportation, contrary to commercial interests, are entirely impractical. As the history of transportation is reviewed 50 to 100 years from now by students who are interested in its development, the influences of the World War will be seen more clearly than they are at present. We are still too near the war for every one to gain a clear perspective easily. Those who know have not yet completed writing the full, comprehensive accounts that will make up the history of the world's war-time transportation. This much can be said, however, as it has happened in every other great human activity, as it happened in Europe after the Franco-Prussian War in regard to railroad transportation; the war will influence post-war development of transportation in direct proportion to the intensity of suffering or of success which attended war-time experience. England will not forget the Somme. France knows the importance of organized highway transport, as it undoubtedly saved Paris in 1914 and 1918. Germany will remember that when her advanced armies were almost in sight of Paris they could not go on, or even hold their ground, because the extended German transportation system failed to move up the required supplies.

The United States, saved from suffering any reverses or extreme anxiety by an armistice that was signed within 6 months after serious American fighting began, is more apt to miss the significance of the war's great teachings. Already we have shown that we do not consider it necessary to control the overseas transportation of our imports and exports. The relation which a sea transport, when coordinated with our railways and highways, might bear toward regulating the overproduction on our farms with the starvation which has been rampant in foreign countries, has not been understood. Perhaps those millions who starve could not have paid for our supplies and transportation. Certainly those who die can never trade with us in the future. Perhaps it is just as well for us to let the sea and foreign markets take care of themselves until we have solved the problem of our continental transportation. Here we have live questions of overland and inland-waterway transport to settle. Shall they continue as separate, independent establishments competing with each other, destroying valuable public investments of yesterday to enhance the value of new investments of today, or shall tomorrow's investments be combined and coordinated with those of today and yesterday to save our capital, produce new earning power and build for us a system of freer movements that shall effect greater savings and profits for carriers and shippers, for labor and capital, for the entire population of our Country?

I certainly believe that all this can be done, not by killing competition, not necessarily by Government ownership, but by private enterprises that are joined to effect powerful combinations in rail, water and highway transport.

The experiences of war which I have recounted to you and recent happenings in regard to commercial transportation give ample evidence as to how these bene-

[6] See *Journal of the Royal United Service Institution* (London), November, 1921, p. 699.

fits may come to us. On Jan. 27, 1923, a distinguished group of transportation executives met in New York City at the call of Julius H. Barnes, president of the Chamber of Commerce of the United States. The Secretary of Commerce, Herbert Hoover, was present. The resolutions drawn up at this meeting have been published[7] and are familiar to all transportation men. They provide for a comprehensive study of the whole question of national transportation with a view to formulating a "coordinated national-transportation policy."

Our cabinet ministers have been discussing national transportation. At a recent meeting, I am informed, the subject of our coast-to-coast traffic came up for consideration. Government figures indicate that, if the traffic which passes through the Panama Canal continues to increase at the present rate, the capacity of the canal will be reached in a comparatively few years. The question of enlarging the Panama Canal or of establishing a new and shorter route by digging the Nicaraguan Canal arises, the idea being to relieve congestion on the transcontinental railroads. This is another long link in our national network of transportation which must be coordinated with railway and highway transportation.

On Dec. 7, 1922, President Harding, in his message to Congress said:

> Manifestly, we have need to begin on plans to coordinate all transportation facilities. We should more effectively connect-up our rail lines with our carriers by sea. We ought to reap some benefit from the hundreds of millions expended on inland waterways, proving our capacity to utilize as well as expend. We ought to turn the motor truck into a railway feeder and distributor instead of a destroying competitor. . . . Costly highways ought to be made to serve as feeders rather than competitors of the railroads, and the motor truck should become a coordinate factor in our great distributing system.

The Army has been working along these lines for several years and already has such a plan which it is ready to present as a peace-time industrial-service and a step forward in national defense.

THE ARMY PLAN OF HIGHWAY TRANSPORT

National plans for coordinating transportation facilities in the United States and for developing highway transport in commerce as the coordinating factor, should be based on the best and broadest practices developed during the unusually heavy traffic strains of war. The motor-transport organization in the Service of Supply in France forms a very definite background for the study and planning of highway-transport organization in the United States. Some idea of the plan of the centralized Motor-Transport Service in the S. O. S. in France can be gained from a map, which is reproduced in Fig. 1, showing the motor-transport repair-activities in the Service of Supply, A. E. F., as they existed on Nov. 11, 1918.

The resemblance of this motor-transport maintenance organization in the Service of Supply, A. E. F., to the plan of a National Motor-Transport Service in the United States is striking. See Fig. 2. The concentration of population and motor vehicles and the close network of improved highways and motor-transport centers in the northeastern portion of both maps make the two problems appear much alike.

The Army plan for organizing a National Highway-Transport Service in this Country and for coordinating it with Railway and Waterway Transportation has been developed in several recent studies which have been incorporated into a base plan for the United States. This plan of a nation-wide motor-transport service might be developed privately in commerce or publicly for war or other emergency, wherein the objects sought are freedom of movement in general transportation with the greatest effectiveness and economy of effort and capital invested.

This is not an academic study for war or other emergency. It is true that it will serve in such events as a basic plan, from which to construct operating plans to fit the general circumstances and special requirements of whatever emergency may arise. The primary purpose of this presentation is purely for the benefit of commerce and public economy. The benefits of this plan, which will first be felt among the truckers in making operation and maintenance financially safer and more lucrative, will, I confidently believe, quickly spread to railway and waterway carriers, and thereby, with multiplying effect to transportation capital, transportation labor, the shipping and traveling public and finally the Country generally. This plan suggests organization of highway transport as the coordinating factor in general transportation. Its details are not complete, but its principles have been sufficiently tested to prove their value as a foundation upon which to build.

This plan will serve as a basis upon which trucking companies can combine in any city, state or group of

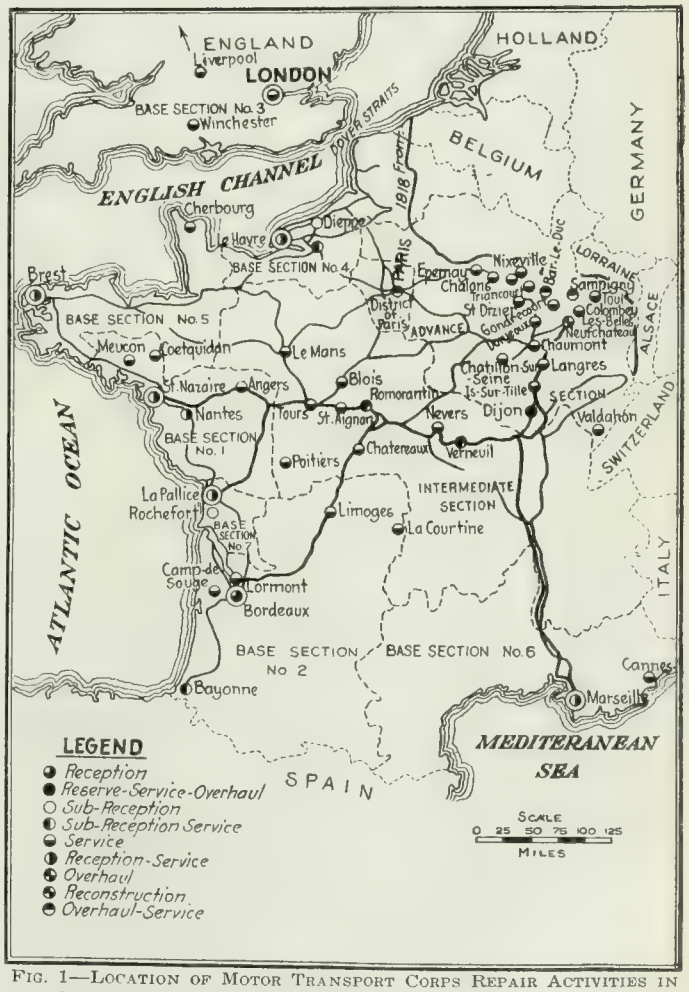


FIG. 1—LOCATION OF MOTOR TRANSPORT CORPS REPAIR ACTIVITIES IN THE SERVICE OF SUPPLY, A. E. F., AS THEY EXISTED NOV. 11, 1918

These Activities Embraced All Automotive Repairs for the Entire A. E. F., except Minor Repairs of Vehicles Made by the Combat Divisions in Battle Areas. Rail-Heads and Motor-Transport Centers, in Other Words Traffic Centers, Were in the General Vicinity of These Repair Activities

[7] See *Automotive Industries*, March 8, 1923, p. 578.

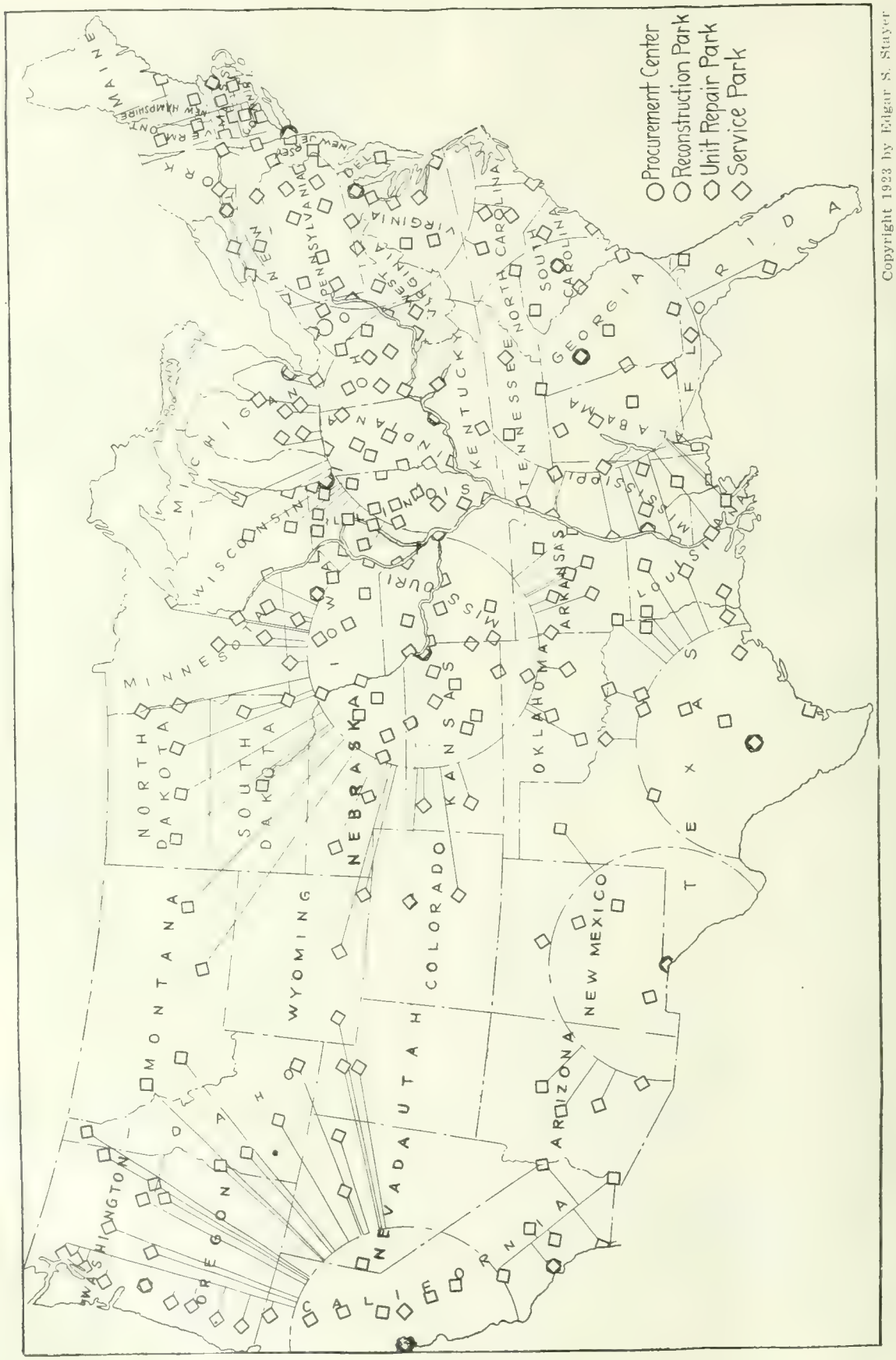


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FIG. 2 AUTOMOTIVE MAINTENANCE ACTIVITIES REQUIRED TO SUPPORT A NATIONAL MOTOR-TRANSPORT SERVICE

The Maximum Economy in Vehicle Maintenance and Plant Operations Are Gained through the Centralization of Procurement, Major Repairs and Control over All Maintenance Functions at What May Be Termed Central Powerplants in Highway Transportation Indicated by the Centers of the Very Large Circles

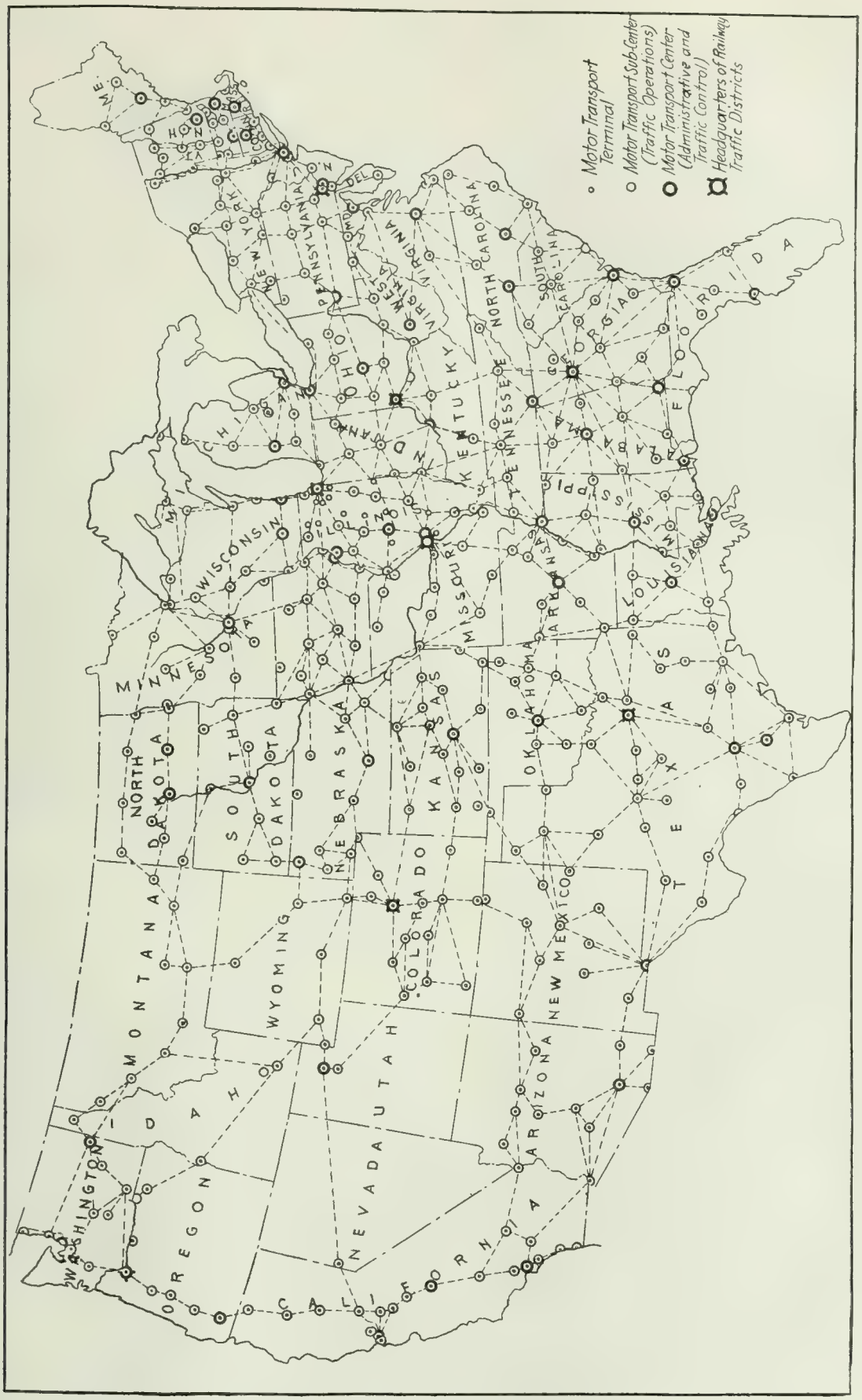

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Fig. 3—General Traffic Centers and Highway Transport Centers Combined into a National Plan of Coordinated Transportation

In This Plan Terminal and Port Facilities Are To Be Developed at General Traffic Centers To Coordinate Railway, Waterway and Highway Transportation. Highway Transportation Is To Be Organized around the Highway Transport Centers and Operated as the Coordinating Factor in General Transportation. The General Principle of Making Long Hauls by Railway or Waterway and the Short Hauls, Such as the Collection and Distribution of Less-Than-Carload Freight and Door-to-Door Services, by Highway Transport Is Followed

states in the larger organization of highway transportation, found in war-time service to be the only kind of motor-transport organization that would permit the realization of very great economies in operation and maintenance. These larger organizations produce more effective and therefore more profitable traffic operations. They permit a reduction in vehicles in congested streets without restricting the general production and sale of vehicles throughout the Country. Many of the congested traffic problems, now puzzling city engineers, will automatically disappear under good centralization in organizing highway transport. The plan will serve as a basis for combining railway, waterway and highway-transportation companies, for the realization of even greater economies in joint operation and maintenance than are possible in separate operation and maintenance. The plan is particularly applicable and interesting in the study of national-transportation policies which are being contemplated with a view to coordinating all transportation facilities. Lines of thought and effort in all the different activities that go to make up our national scheme of supply and transportation can be given a general direction and coordination by the adoption of a basic plan like this in private enterprise, industrial commerce or public emergency.

On the map of a "National Motor-Transport-Service," shown in Figs. 3 and 4, traffic centers are indicated by small circles drawn with a radius of 10 miles, as per map scale. These have been established by many Army engineers working in the field on this study. They are tentative centers only and may be abandoned or replaced by others as the study proceeds or changes. The principles which apply to the selection of traffic centers are as follows: Highway-traffic centers should coincide with railway and waterway-traffic centers to make possible the practical coordination of terminal and line operations, in all three transportation systems. The general-traffic centers thus formed should be reduced to a minimum and located so as to permit the reduction of terminal operations and overhead costs, with the maximum control over traffic in all three systems, using rail and water transport for long hauls and highway transport for collection and delivery and for short and broken hauls.

The following important requirements are fulfilled in the National Highway Transport Service planned by the Army in its proposed general plan for coordinating our national transportation facilities. The principal railway systems of the United States pass through and connect the principal general-traffic centers tentatively selected. The principal Coast and Lake ports coincide with important general-traffic centers. The navigable rivers and canals, shown in our river and harbor projects, also pass through the principal centers located in the vicinity of such waterways. Most of the highways shown in our federal-highway project, a project of the greatest national interest and importance, pass through the principal general-traffic centers. The principal highways already in existence, improved and unimproved, as shown by the Automobile Blue Book and American Automobile Association maps, pass through and connect almost all of these general traffic centers. The principal Blue Book routes are the ones used in this particular study.

The majority of these general-traffic centers, as they now stand, occupy positions of great strategic value in our national commerce, and in any scheme of national transportation which may be considered. Highway transport organizations established at these points will be able to participate in, if not control, most of the highway movements of the Country. They are in close proximity to the great markets and storage centers, and within easy trucking distances of all the collecting and delivery points in the fields of our principal industries; agriculture, transportation, manufacturing and mining.

If any serious disaster ever threatened this Country, an emergency transportation system could be organized quickly on these points with absolute certainty of establishing a basic network upon which to hold our Nation together, with sufficient means of movement to assure our people of a regular supply of food, fuel and other necessaries of life. If commercial war between railroad transportation and highway transportation should unhappily result from a failure to find and adopt a general plan for coordination and cooperation in overland transportation, these or similar points, because of their relation to the general traffic of the Country, will prove to be commanding points in the contest. Until other centers are added or substituted, these will serve for further study.

If the science of transportation is the same in commerce and war, and success in applying such a science depends upon the superiority with which the factors that enter into transportation are combined and operated, we can dismiss the thought that this plan smacks of war and emergency and confine our thoughts solely to commercial requirements, content that it has been proved in war and will work for the public good in emergencies. We will turn our thoughts toward solving the transportation problem for expanding traffic, future railroad-blocks and congestion due thereto, unsatisfactory financial conditions, riddles in truck and highway development and the troublesome question: "How will motor transport affect the railroads?" The details of just how this or any other national plan of transportation will be developed in commerce must be left to commerce. The Army can simply outline general procedure of a cooperative nature.

To demonstrate this study fully, it will be necessary to assume certain steps and actions. Assume that the Pennsylvania Railroad and other large railroad systems called meetings of the leading truckers along their lines to consider ways and means of developing a highway transport, to operate from traffic centers, mutually established at strategic points, in a service of highway collection and distribution, primarily, with regard to railroads, and assume that they all used this Army plan as a basis upon which to work up their resolutions. It would not matter vitally whether the railroads established ownership over the highway-transport organizations which might be formed at these traffic centers, or simply agreed to do business with them if they combined and subscribed to contracts which would establish a means of coordination and avoid unscientific competition and consequent economic waste.

Assume, if you will, that the Society of Automotive Engineers or the Chamber of Commerce of the United States called such a meeting, or several meetings, of truckers throughout the Country to consider ways and means of organizing highway-transport centers under this general plan. Such companies might combine along the principal railroad systems or within a state or group of states, and then effect business contracts with railroads, steamship lines and industrial and mercantile firms to handle terminal operation, less-than-carload freight and door-to-door services.

Many such highway or motor-transport companies might form in these or other centers. Their organization, if in conformity with this or any other general plan, would constitute a national system of coordinated transportation. All transportation agencies might not sub-

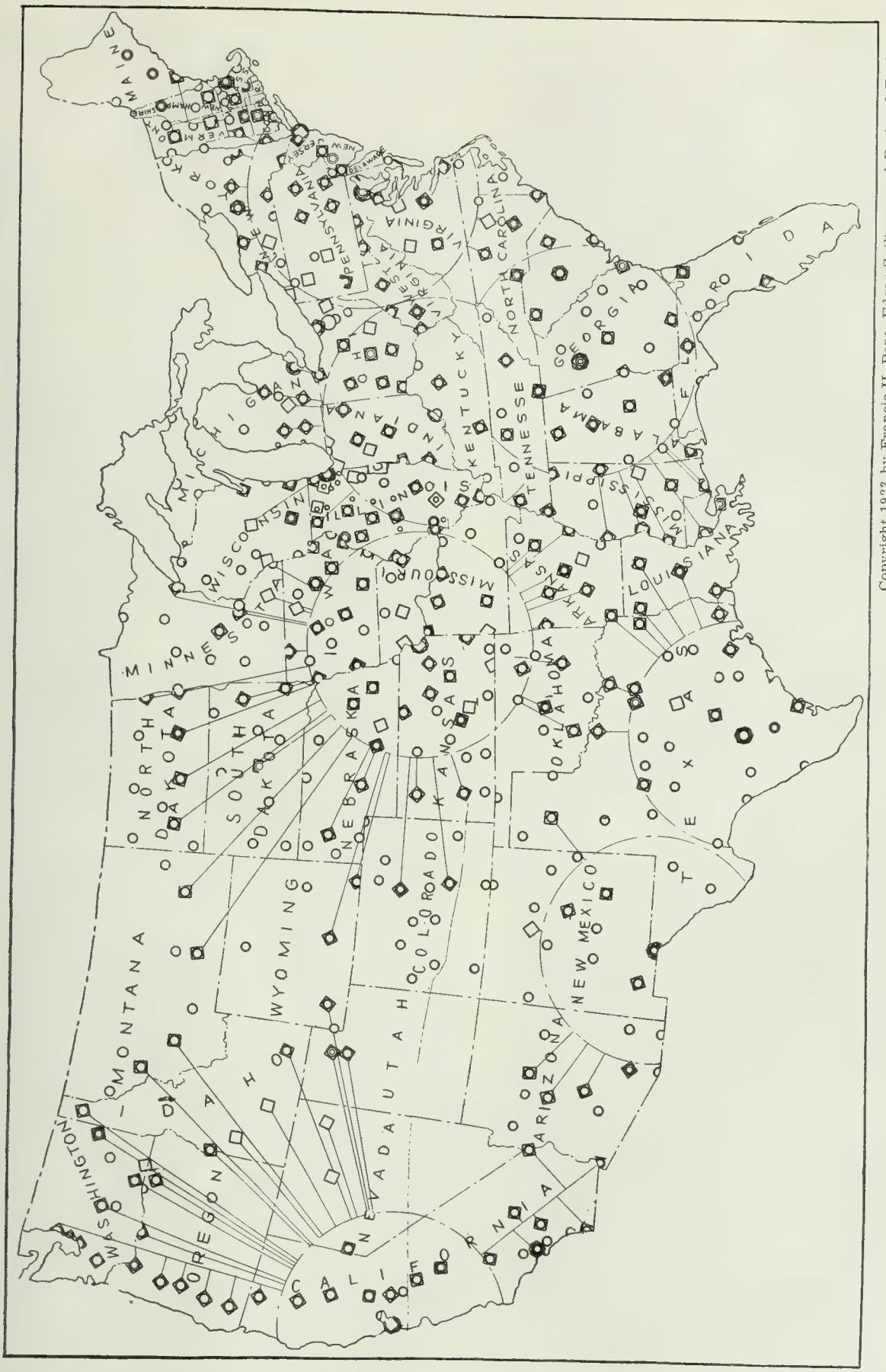

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FIG. 4—A NATIONAL MOTOR-TRANSPORT SERVICE COMBINING THE FIELD OF OPERATIONS AND TRAFFIC, SHOWN IN FIG. 3, AND MAINTENANCE ACTIVITIES, SHOWN IN FIG 2
This Map Might Represent Any Public or Private Service of the Future Operating on a Nation-Wide Scale or the General Plan of Future Highway Transportation in Commerce under a National Policy of Coordinating Rail, Water and Highway Transport

scribe to this or any general plan. The fact that a number throughout the Country did subscribe or conform to a general plan which would provide for centralizing coordinating functions over their general transportation systems would be sufficient to establish a skeletonized, national, coordinated transportation service. The formation of such organizations would not stifle the principle of competition. It would tend by natural methods to enforce the adoption of similar or better principles under the stress of business competition, just as it did under military competition in war. General adoption of such a plan would enable all conforming transportation companies to join quickly, for a temporarily combined service, under Government direction or coordination, in emergencies, without the confusion, waste and injury to private ownership that has attended past emergencies. Conforming companies could fit quickly into the general network of national transportation, and could operate with their normal personnel and machinery under a common plan, the general principles of which were not different from their habitual practices.

Even if no such combination as this plan suggests were ever made between railway, waterway and highway-transport companies, the principles of the Army plan might be made to render a great public service by coordinating the policies of railroad and highway development. It forms a reference on file in Washington which the two great transportation industries can use to work out amicably and with mutual benefit problems of highway construction, maintenance and taxation. It shows definitely how motor transport can be organized to aid and not injure railroad transportation. There could be no material differences or commercial war between the two industries, were they to adopt such a coordinating plan as this and cooperate with each other as it provides.

In the construction of highway systems alone, some national coordinating plan like this is needed before we expend hundreds of millions of dollars on highways that may not be in accord with national policies affecting general transportation. The railroad companies as a whole are interested in the general character of the highways that are to be constructed. If truck highways are to be long trunk-line affairs paralleling the railroads and suggesting competition with them in long hauls, we may be sure there will be, sooner or later, a commercial war between the railroads and the truckers. If highways generally radiate for comparatively short distances from railway terminals and stops, obviously to provide highway transportation for the collection and the distribution of railroad cargoes, the railroads must soon give hearty support to such a program of highway construction.

We need, of course, long highway routes from the East coast to the West and from Canada to Mexico, for touring, for national defense and for supplementing railroad transportation in periods of railroad-traffic blocks and other transportation emergencies. These will not be opposed by the railroads in any such national plan as this, which emphasizes the importance of radial and belt-line highways constructed with reference to railway-traffic centers.

Nothing could be worse from the point of view of the automotive industry, or the public, than to spend many millions of dollars of public funds in constructing highways that failed to show a reasonable profit in commercial use. It would not be long before there was developed a situation wherein capital for road and truck construction would be hard to get. Such a situation would surely follow a successful fight by the railroad interests against the construction and the commercial use of automobile highways. The railroads themselves would lose, potentially, very heavily were they forced to take such defensive action through an unwise, blind or uncoordinated and competitive policy in highway-transport development.

Development of the Army Plan

You will find the successive steps taken in developing this plan both interesting and clarifying. The subject is too immense, of course, to show much of any detail in a map of a nation-wide transportation system. I will begin with a city and work up to this national plan. Shortly after my return from France, in March, 1919, I was assigned as Motor-Transport Officer of what was then the Eastern Department, on the staff of the Commanding General at Governors Island, N. Y. The area was a large one, embracing all military activities in the states of New York, New Jersey, Delaware, Pennsylvania, Maryland and Virginia, including the City of Washington. The Army Motor-Transport Service in that area in March, 1919, was completely decentralized, and, in consequence, suffering from the same evils and extravagances we had experienced in our early service in the A. E. F. The centralization of automotive repair and supply in large depots like Camp Holabird, Md., Camp Jesup, Ga., and Camp Normoyle, Tex., was understood as completing the organization of the Motor-Transport Service. Organization of the traffic or operation branch and the organization of centralized administration had not been accomplished. With the decision of the Commanding General of this area, so important from a transportation point of view, to organize a centralized service of motor transport there was presented an exceptional opportunity to make a practical study of the transportation problem here in the United States, immediately following the completion of the A. E. F. experience.

The "Port of Embarkation" situated in New York City, in Brooklyn and in Hoboken, N. J., had a very active and extensive motor-transport service but, because of its separation from all surrounding motor-transport activities, it was also a very expensive one, absorbing all the funds allotted for its operation that should have taken care of many near-by, small, isolated fleets of Army vehicles over which there was no effective supervision.

The plan of centralized service was applied as well as it could be, except to the New York Port of Embarkation, during the difficult period of rapid demobilization of 1919 and 1920 and the consequent loss of experienced motor-transport officers and men belonging to the temporary forces. In February, 1920, the entire motor-transport service of the Port of Embarkation, which had been operating independently at a cost of about $1,000,000 per year, was turned over to the centralized motor-transport service of the Second Corps Area, operated from Governors Island, with instructions from the War Department to reorganize it within the month as part of our centralized service. We were informed that it would be necessary to operate the entire service, in all five States, including the Port, for $78,000 per quarter, beginning March 1, 1920. Such a radical change could not have been accomplished without great confusion under any other plan than this plan of centralization. With the wholesale laying-up of motor vehicles and the discharge of drivers and mechanics that was immediately necessary, transportation problems were greatly complicated. The change was accomplished, however, without exceeding the greatly reduced allotment and without undue confusion.

Under this plan, motor-transport centers, or pools, as they were called, were established in or near the cities of New York, Trenton, Philadelphia, Baltimore, Washington and Norfolk. Experienced motor-transport officers were put in charge and given authority to supervise the organization of all motor-transport operations and maintenance of fleets located within areas designated as belonging to their pools. The more important points in the vicinity of these cities were called sub-pools, and the garages and fleets in their vicinity attached to them for supervision. The entire system was then administered generally and coordinated from the central office at Governors Island, N. Y.

Nothwithstanding the continued loss of experienced personnel by demobilization and increase of work to the reduced forces, there was a steady improvement in the condition of vehicles and a marked economy in their use and repair. By these improvements, quickly and easily effected through center or pool executives, and by coordination with rail and water transport, the volume of movements, which could not be stopped at once with demobilization, was taken care of, the cut and change of service being made within less than one month from the time orders were issued in Washington.

Traffic Center of New York

Greater New York was, of course, the most interesting point in this centralized motor-transport service. A brief description of the New York service will serve as an example of the service indicated in each one of these traffic centers, proposed in the Army plan.

The motor-transport executive who controlled the New York center or pool, as it was then called, had an office at the corner of Eighth Avenue and 33rd Street. Here was a typical setup of a Motor-Transport Center office described in the Army plan. The administrative functions for the whole group, consisting of the New York center and near-by sub-centers, that is, all matters pertaining to personnel, finance, internal coordination and general business with outside agencies were centralized here. The Operation of Traffic branch had its main office here under close executive supervision. The chief dispatcher of the New York center operated from this office, directing by telephone the movement of all vehicles from garages located at 59th Street, Tenth Avenue, Governors Island and one or two other points on Manhattan. Through branch offices and assistant dispatchers at the Army Base in Brooklyn and at Hoboken, he also directed the movement of all vehicles from garages located across the two rivers.

The location of Army garages, shops and service stations and all railroad yards, docks and routes and the general points of Army collection and delivery, were shown on the dispatcher's map. All vehicles were posted on his control boards and their location and duties and status were shown at all times. Officers and men skilled in loading trucks and handling freight went constantly to freight yards and steamship docks to supervise and expedite the loading or unloading of freight. These officials are described in the Army plan as "Cargo Spotters." The loss of time and the confusion at docks and yards, due to the lack of coordination between the railroads and the steamship companies and the outside trucking corporations, was the most outstanding feature of this part of the service. It showed the need of creating cargo spotters in the Motor-Transport Service to work with railroad officials in expediting the exchange of cargoes between rail, water and highway transport. In addition to this freight service, an extensive taxicab service and a motorcycle mail-and-messenger service were also operated.

All calls for the movement of passengers and freight were telephoned to the chief dispatcher, although they might be received originally in branch offices or garages. The chief dispatcher consolidated and coordinated them, arranging for collections and deliveries and the hauling of full loads and return loads. Cargo spotters supervised proper loading. The chief dispatcher issued his trip tickets and way-bills and directed the necessary movements much as though he were a railroad dispatcher.

The chief dispatcher was furnished, from other sections of the operating office, all necessary information regarding vehicle equipment, passengers and cargoes, their origin, destination and description, and terminal and road conditions. He fitted these factors together in making up his plans of operation and orders. With the necessary assistants in his office and in the field, through a well arranged system of telephone communications, he rendered passengers, shippers and consignees a very effective and economical highway-transport service. Under the traffic engineer, the chief dispatcher was in actual control of Army highway traffic at all hours of the day or night.

The Maintenance Branch of this New York Motor-Transport Service, although under the jurisdiction and a part of the center executive's office establishment, actually had its office in another building with its main repair shop. What we call overhaul jobs, that is, any job requiring a vehicle or unit to be knocked down and disassembled, all battery and magneto repairs, body and upholstery work and tire repair of a general character, all these were centralized at the overhaul park or shop, located while under the Port of Embarkation in the heart of the city, but later removed to Sandy Hook, N. J., for economy.

This was a very good city service organized and developed during the war by Port of Embarkation authorities and reorganized later to embrace outside activities on this plan of centralization. It was not perfect under the difficulties of demobilization that hampered its reorganization and operation, but it had distinct advantages over the prior decentralized service. These were sufficiently obvious to receive enthusiastic support from General Bullard, who commanded at Governors Island, and from the War Department which was chiefly interested in gaining effective and economical transportation with its greatly reduced means. The City of Washington also had an excellent city service of zoning and dispatching vehicles, and of coordinating highway transport with rail transportation. Col. G. A. Green, then with the Fifth Avenue Coach Co. in New York City, showed me an extremely well planned system of operating and maintaining a city bus service, wherein a fleet of less than 300 buses gave a general impression that there were 10 times that number. The principles of organization in that company, especially relating to the coordination of traffic and maintenance functions under one head, were in accordance with the best practices in war-time motor transport in France and with this Army plan of a National Motor-Transport Service. There are several commercial plans for operating the motor-transport service of a city bus, taxicab or trucking service which, in many features, are better and more complete than any we have ever had in the Army, I am sure. The best should be available for any national plan. I will not attempt to go further into the details of city or small-fleet operations. It should be enough to know that the Army can furnish the details of a very satisfactory local service if required,

upon which to develop the details of a city or center motor-transport service.

Commercial Organization Under the Army Plan

Assume that, say in Cleveland and its vicinity, a dozen of the principal trucking companies were to combine under the name of the Cleveland National Highway Transport Service. This corporation, we will assume, acquires enough garages and vehicles to carry on an extensive service of highway transportation, not only within the city of Cleveland but through the outlying country for a distance of several hundred miles in any direction. At Painesville, Ashtabula, Youngstown, Canton, Akron and Lorain there are established fleets of the corporation's motor vehicles. Capitalization, franchises, contracts with other carriers for coordinated services and contracts with shippers and consignees are provided for, we will assume. With the standardization of equipment it will be found that this corporation can make all its own major repairs, except out-and-out reconstruction, better and more cheaply in its own centralized shop at Cleveland, under the good shop management of an efficient automotive engineer, than it could get them made by outside agencies, in the towns named above.

Say that this automotive engineer located in Cleveland is given charge, not only of the Cleveland shop, but of the whole system of repair and supply in the area covered by the Cleveland National Highway-Transport Service. He prepares to keep the active vehicle equipment throughout the service up to a fixed number of reliable vehicles by working in close harmony with the traffic engineer of the company. His attention is centered on the problem of maintaining the current, capacity and power of the traffic service rather than the repair of a number of vehicles and the running of a shop and warehouse. His direct responsibility, however, is for good repairs and good shop and warehouse management. The keynote of his repair policy is "unit replacement to all operating fleets," centralizing unit repairs at the Cleveland shop.

The traffic engineer of the corporation controls all vehicles considered to be on an active basis. He cooperates with the maintenance engineer at garages for the regular inspection and the caretaking of active vehicles, and for timely adjustments and minor repairs. He cooperates with railway and waterway-traffic managers at railroad yards and docks. Through his dispatchers he operates the entire terminal and highway service as I have indicated in describing the Army Motor-Transport service in New York City.

Assume further that the two engineers, traffic and maintenance, are controlled and coordinated by the Highway-Transport Engineer who is the general manager of this Cleveland National Highway-Transport Service. This official should combine a knowledge of both departments under him, of cost accounting and finance and the general transportation and industrial conditions which affect the operation of his combined motor-transport service. He maintains a constant supervision over traffic and maintenance matters by frequently inspecting all activities in both branches. He, or his representative, and his inspectors constantly ride over the area covered by the Cleveland corporation, watching operations and gaining, through personal contact, first-hand knowledge of conditions, internal and external to the highway transport service, which affect its welfare.

The management of all offices, garages, vehicles, shops and all elements of this proposed highway-transport service, located within a radius of approximately 50 miles of Cleveland, unless the service becomes too large to manage from one office, is centralized in the Cleveland office. Under the Army plan, this would constitute the Cleveland Highway-Traffic Center. Where the service at cities like Ashtabula, also a traffic center, within the approximate 50-mile limit requires more of an administrative supervision than that given by a garage manager, a branch office called a sub-center is established from the Cleveland center. Sub-centers are also established at traffic centers outside of the 50-mile limit like Mansfield, Columbus and other points, and all highway-transport activities belonging to the Cleveland company, located within 50 miles of these traffic centers, are attached to them for management on the same principles as governed the organization of the Cleveland center, except in the matter of major repairs and general administration. Maintenance and administrative overhead are kept down by centralization as much as possible at Cleveland; local traffic administration and coordinating control only are conducted from sub-center offices. In the Cleveland Highway-Transport Group, thus built up, covering perhaps an area of 10,000 sq. miles or more and composed of one center at Cleveland and as many sub-centers as may be found to be necessary, the principal features are these:

(1) Business administration, general traffic control and detailed maintenance control are all centralized in one office, called the Cleveland Highway-Transport Center

(2) Special functions pertaining to administration, maintenance and direct control over local traffic are judiciously decentralized to sub-centers for execution under general supervision from the main office

(3) Fleets and garages are located wherever necessary

(4) A "Reserve Pool" of inactive vehicles and units, located at convenient points within the area, is established under center or sub-center control. This reserve pool forms a buffer between the operation and the maintenance programs. Garages rotate vehicles in operation, 6 days active, for instance, and 1 day inactive for adjusting and caretaking. Vehicles and units requiring more than minor repairs, necessitating more than 24 inactive hr., are sent to a service shop and the vehicle or unit is replaced from the center or sub-center reserve pool. Maintenance programs work on these reserve pools by the system of unit replacement mentioned heretofore, shipping all vehicles and units requiring disassembling to the main shop at Cleveland. Mechanical units are dismounted from vehicles at service shops only. No dismounting or dismantling is ever allowed at garages

Other groups similar to the Cleveland group might be formed in the same way. If they belong to the same corporation or combination as the Cleveland National Highway-Transport Service, they should centralize their vehicle procurement, their major repairs or overhaul jobs, warehousing and general reserve stocks at some central point such as Cleveland. A combination formed along the Pennsylvania Railroad system might centralize at some point more central for the larger combination like Columbus. A reconstruction park is justified only by an equipment of 400 to 500 vehicles. It is designed to make every conceivable repair or reconstruction required, without outside help. The radius of maintenance control exercised from such a central power-plant in highway transportation, is approximately 500 miles. It may establish branch shops called "Unit Replacement Shops" at other points, wherever the density

of vehicles, the cost of transportation or any other good reason calls for such establishments. Very general administrative and coordinating control over very large areas, particularly with regard to coordinating with railway and waterway transportation, may also be centralized at one of these Highway-Transport Central-Power plants.

These consolidations will never be uniform nor shall we be apt to build up very quickly such a system as this plan shows if they are left to form from the bottom; that is, the forming of natural combinations among the smaller trucking companies, without any guiding plan indicating definite points upon which to concentrate. General-traffic centers should be decided upon by leading transportation engineers in the Country who mean to guide our destinies into general coordination rather than competition. Centralization and coordination of the three services should be worked out upon such points.

The grouping of motor transportation will take care of itself. Highway traffic is subject to change and will always fluctuate with changing conditions of general traffic, as it is affected by peak loads, seasonal changes and changes in our industries. The principal railroad lines and natural-waterway lines should form the arteries of all highway-transport organization. These arteries should be protected as much as possible from sudden and temporary changes in transportation conditions by the operation of highway transport. When an extensive organization in highway transport and the coordination of general transportation is accomplished, concentration of highway-transport equipment can be made in different parts of the Country to bring about the timely movements of peak loads, and in accordance with seasonal changes. The harm done by "fly-by-night" trucking companies at present in taking the cream of business away from local companies could then be controlled. Railroads and steamships could be used to help such truck concentrations.

With regard to the successive steps in developing a nation-wide plan, the Army study of a National Motor-Transport Service, and its place in a National Coordinated Transportation Service, was based on the following premise: "Motor transportation in the United States can never either in an emergency or in daily commercial practice replace the long-haul service of railroads."

Location of Traffic Centers

As a first step in the Army study, an important central section of the United States embracing Indiana, Ohio, Kentucky and West Virginia, was selected. Half a dozen railroads running through this territory were assumed to have combined with each other and with inland-waterway and trucking companies to develop a coordinated transportation service. It was assumed that they agreed to conduct all long hauls of 50 miles or more by railway or waterway, as a general rule, giving the public the choice of the various benefits, that is, speed convenience, cheap tariff, door-to-door service and the like, now at the command of the combined transportation companies because of their water, rail and highway services. They were to coordinate the three services so as to reduce the overhead of administration, maintenance and terminal costs among themselves and feed passenger and freight traffic to each other as much as possible, relying on the producing of new business and on savings for their increased revenues rather than on high tariffs. Inasmuch as short hauls, up to an average limit of 50 miles, were to be made by highway transport, railroad terminals and stops, at least 50 miles apart, were selected along the

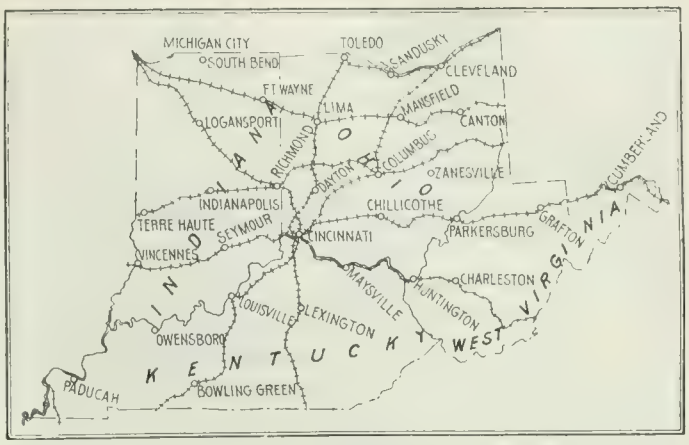

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Fig. 5—General Traffic Centers, Indicated by the Small Circles, Are Selected Points at Which Terminal and Port Facilities Are To Be Developed, Similarly to the Present Development of the Port of New York, with the Basic Idea of Coordinating All Transportation Facilities by the Practical Development of Cooperative Terminal Operations

railroads designated for study to form general "Traffic Centers." At these points, it was assumed, terminal facilities would be developed with a view to cooperating to the fullest extent with the highway-transport service. Intermediate stops and terminal operations, especially with regard to handling less-than-carload shipments were to be eliminated by railroads. Carload collection and delivery stations might still be provided for, when shown to be cheaper in transportation or to give more expeditious service. Commutation and express services might be arranged for by rail service, bus service or both.

Water transportation, operating from Lake ports and along the Ohio River, was treated in the same manner as for railways. The map showing the first phase of this study appears as an outline railway-and-waterway map with very few stops in the area under study; it is reproduced as Fig. 5.

Formation of Highway-Transport Centers

The second phase of the Army study concerns the organization of the highway-transport service. The rail and waterway terminals and stops, or traffic centers, constitute foci about which to organize local motor-trans-

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Fig. 6—Highway Transport Centers Are Formed about All General Traffic Centers Shown in Fig. 5

These Are the Points in the Highway-Transport System about Which Highway-Transport Development Should Take Place. Three Classes of Highway, Arterial, Radial and Belt Line, Are Indicated

port and animal-transport services, and from which to develop a system of radiating highways for the collection and distribution of rail and waterway cargoes. These highways must be coordinated and joined by arterial or trunk-line highways connecting all traffic centers in one comprehensive highway system. All important traffic centers should be provided with belt-line highways for transfer services and to provide detours for all through, non-stop highway-transportation so as to avoid adding to the congestion of city streets. To organize the highway-transport service that is to operate from these traffic centers, and to control and coordinate highway traffic with relation to rail and water transportation operating in the general transportation service under development, a circle was drawn with a 10-mile radius on the map to indicate the establishment of a highway-transport center as part of the traffic center established by the railroads. The 10-mile circle which suggests a belt-line highway also indicates the average limit of the city collection-and-delivery service for each traffic center. (See Fig. 6.)

The average limit of country collection and delivery, in motor transportation in areas over which the highway-transport service is to operate from each traffic center, was fixed by boundary lines, established with reference to a circumference drawn about each traffic center with a radius of 50 miles. The imaginary circumference itself might be used, although natural boundaries like rivers, mountain chains, railroads, highways or State and county lines are preferable. In selecting these boundaries the 50-mile radius was used as a general guide only. Local conditions govern in each case.

The establishment of highway-transport centers and sub-centers and their grouping for convenience in administration and traffic control, as described for the assumed Cleveland National Highway-Transport Service, was indicated by the approximately 50-mile boundaries and by colors as shown on a third map of the area under study. (See Fig. 7.)

The organization of each group is similar to that which I have described for Cleveland and its vicinity. The vehicle equipment employed at each center depends upon a calculation of the tonnage and the character of the different commodities to be handled, road conditions, standardization of vehicles and other highway-transport considerations, presented for each center but considered and determined for the entire highway-transport service, as it is organized and developed.

Amplification of the Army Study

This sample initial study was sent to all the principal Army headquarters in the United States, with a short pamphlet of instruction. Transportation engineers at these headquarters were directed to submit to the War Department highway-transport map-studies of designated areas, to be made in accordance with the principles of this sample study, applied to actual local conditions. These studies have all been received and reviewed in the War Department. In some cases they were sent back for revision, but were finally accepted and combined to make a single map-study of highway transport for the entire United States.

In the original joint study, made by officers in the Engineer Corps, the Quartermaster Corps and the General Staff, both in the War Department and in the field, all over the United States, the principal roads shown in the well known Automobile Blue Books were used, in order that we might all work on the same highway system, representing roads already in existence and in some degree suited to highway transportation. These roads are far from what is required for national highway transportation, but they are better than Federal and State highway projects for immediate purposes. Further studies are being made with the American Automobile Association map-system of roads. Here again we are confronted with the great defect in our network of transportation. The absence of improved roads and bridges suitable for highway transportation appears as a serious weakness in our national transportation system. Industrial progress in unimproved areas is seriously retarded. Were motor transport required to operate over these unimproved roads in public emergencies, the cost in damage to motor-vehicle equipment would be incalculable. (See Fig. 3.)

The problem of organizing a National Highway-Transport Service is best considered for the present by leaving out of the maps illustrating its organization all highways and even the basic railroads assumed for the original study, retaining only the traffic centers and the grouping of the motor-transport centers and sub-centers determined upon by the combined Army study. These represent most of the commercially strategical points in any system of national transportation which may be devised. They are near enough to be used in establishing a basic organization, or a basic policy.

The study now appears as a highway-transport traffic-map showing the traffic centers in the field of operations for the Chief of the Operation or Traffic Branch. Through these traffic centers pass most of the railways, waterways and highways, actual and projected, which make up our entire national network of transportation. Any national highway-transport service must operate over such highways as already exist in this network, whether they operate independently in decentralized trucking or systematically in organized highway transportation. Highways that exist can be drawn-in locally. Radiating and belt-line highways required, as well as trunk-line highways urged for early construction under approved State and Federal highway projects, can be drawn-in by each private company, State or Federal group, that may make a detailed study of this plan.

This study of the organization of a national highway-transport service which has been made in the Army from the *traffic* point of view as the point of original and not the automotive procurement, repair and supply point of view, as heretofore, is not complete and would never amount to a row of pins unless supported by a parallel plan of automotive maintenance. The completed traffic plan was therefore submitted by me as the Army's Motor-Transport Traffic-Engineer, so to speak, to the Army's Motor-Transport Maintenance-Engineer, Lieut-Col. E. S. Stayer, who has in turn submitted a plan of automotive procurement, repair and supply, illustrating the organization of the maintenance facilities to maintain this plan of a National Motor-Transport Traffic-Service. Assuming a permanent highway-transport organization of the greatest magnitude to emphasize the principle of centralization which produces the greatest economies in highway-transport maintenance, Colonel Stayer, who has lately succeeded Col. F. H. Pope as chief of the Army Motor-Transport Service in the Office of the Quartermaster General, can best describe the details of all maintenance plans and operations. I will point out its principal features to show its relation to the Operation Service, which is of primary importance in all transportation schemes.

As effective and economical highway traffic and practical coordination with rail and waterway traffic were the deciding factors in centralizing and decentralizing

control over operating functions in the traffic study, so effective and economical maintenance and the coordination with traffic functions decided the centralization and decentralization of control over maintenance functions in the maintenance study. This plan of maintenance organization differs from all others hitherto known in the Army in that it is designed to maintain a centralized highway-traffic service, not merely the vehicles operated. It recognizes the necessity of a highly organized traffic service as the crux of the whole subject of highway transportation, and is prepared to sustain that service at the very highest possible peak of efficiency by keeping the reserve mobility of the traffic service as near the maximum as possible, the maximum reserve mobility being the initial point of starting transport operations with an equipment of entirely new vehicles of the most durable character.

The reserve power and capacity of the Motor-Transport Service is sustained under this plan by maintaining a pool of reserve vehicles and assembled units between the fluctuating traffic requirements and the necessity of maintaining regular repair programs in shop operation. By a rigid system of rotating all active vehicles through the reserve pool for weekly examinations and adjustments, and by the replacing of vehicles and units needing more than a minor repair from "ready-for-service" inactive vehicles and units in the reserve pool, the active vehicles in traffic are always operating at their mechanical best, with reserve mobility to carry them through traffic emergencies. In the meantime, the repair programs in shops go on regularly, economically, with uniform and standard workmanship, unhurried by the irregularities of fluctuating traffic conditions.

In decentralized trucking, this idea of making unit and vehicle replacements through a reserve pool is merely a theory. It has never worked under a decentralized system. Independent truck and fleet operators will never let it work. Each one, as a rule, operates his vehicles until they positively cannot be operated any longer, and then he forces emergency repairs at any cost under a pressure that destroys maintenance programs and all chance of economical practices. It is a matter of organization and engineering administration. It involves an economical question of many millions of dollars every year in both commercial and military motor-transportation.

The problems of organizing motor-transport traffic and motor-transport maintenance are very different. Control over the functions of these two divisions should not be decentralized to the same degree. Traffic control governs in the Operation or Traffic Branch, while shop and warehousing management, and control over procurement and expenditure of equipment and supplies governs in the Maintenance Branch. This is the chief internal reason why a third branch, the Administration Branch, is necessary in motor-transport organization. A general Executive Branch is required to permit specialization in both traffic and maintenance and at the same time to insure their amalgamation and coordination.

Maintenance Activities in the Army Plan

The maintenance plan in this Army study appears on a separate map without traffic features that is reproduced in Fig. 2. At, or near, centers and sub-centers, established to control motor-transport traffic and along isolated highways of great length, service shops or parks are established, indicated on the maintenance map by squares. These shops make minor repairs which require the vehicle to remain inactive more than 24 hr.

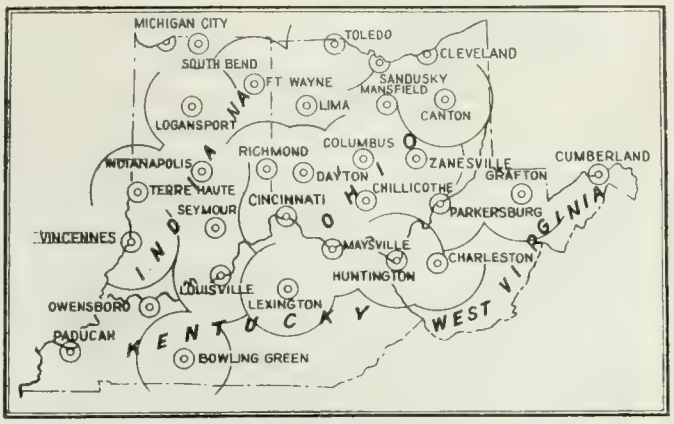

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Fig. 7—A Motor-Transport Service Formed about the Highway-Transport Centers Shown in Fig. 6

The Average Limit of Truck Hauls Is Established about Each Center by Imaginary or Natural Boundaries Determined by an Approximate Radius of 50 Miles. Motor-Transport Centers, or General Administrative Offices, Having Control over General Business, Highway Traffic Control and Minor Repair Work, Are Established at the Most Important Traffic Centers. Nearby Centers Are Designated as Sub-Centers and Only Traffic and Minor Repair Functions over Local Fleets Are Decentralized to Those Branch Offices. The Service Shown by This Map Is Divided in Eight Groups, Each with One Motor-Transport Center and Several Sub-Centers

They also remove and replace all engines and other mechanical units which require extensive repairs. They do no disassembling of vehicles or units, but ship them to unit repair shops or reconstruction shops in exchange for "ready-for-service" vehicles or units.

At selected points, conveniently located to groups and centers, where vehicles are dense and the volume of repair work justifies, unit repair shops or parks are established, indicated by hexagons. Engines, radiators, batteries, magnetos, rear-axle assemblies and other demountable units removed from vehicles at the service shop and sent to unit repair shops for all repairs requiring disassembling, are repaired at these shops on a wholesale plan, or plan of quantity production.

At centrally located points, having excellent supply and transportation facilities, the larger shops and warehouses of the reconstruction parks are located. These, as I have said, are central powerplants in motor transportation. They are indicated by octagons. The practical radius of activity of these parks is about 500 miles, indicated by the very large circles. Where service parks and unit repair parks lie outside the zone of activity of a reconstruction park, they are assigned to the most convenient one for supervision, as indicated by connecting radial lines, so as to preserve the principle of centralization of control over all maintenance functions.

Procurement offices, indicated by small circles on this maintenance map, are located at such natural automotive procurement centers as Chicago, Detroit, Akron, and New York City. The principal maintenance offices are located at the reconstruction parks, from which a general control over automotive repair and supply is exercised for an entire system, as indicated by zones and radial lines connecting isolated maintenance points with the 500-mile circumference of a reconstruction park.

Finally, we reach the map of the completed motor-transport organization in our Army plan of a National Highway-Transport Service reproduced in Fig. 4. The traffic and maintenance centers are brought together in one comprehensive plan. The administrative officers are assigned to stations, according to the importance of these grouped activities, to govern the internal motor-transport organization and apply it to whatever external purposes

may employ its service. A final administrative head as for instance the Chief of the Army Motor-Transport Service in military transportation, controls and coordinates the entire service indicated by this map, in true correlation with all other national transportation systems. In final coordination, such chief executives of motor transport should operate under the coordinating control of the Director General of whatever combination of railway, waterway and highway transportation this Motor-Transport Service is a part. The office of the Director General in national coordinated transportation might be filled by a Director General of Transportation or by a National Board of Transportation, or both. The highways used, or to be used, as I have said before, can be drawn-in on this plan. The railways and waterways with which this service is to operate in a national system of coordinated transportation can also be drawn-in. The map then becomes a general map of coordinated transportation for use in general traffic control, and a basis for general policies.

This study is purely a general transportation study with especial emphasis on the question of organizing highway transportation, using the motor vehicle as the principal coordinating factor. It forms a basic plan upon which any plan of military or commercial transportation can be worked out in detail. A study of the highway-transport service of the United States Post Office Department, the Standard Oil Co. or any general or specialized service of transportation which might be proposed for organization, would look the same in general character if made in accordance with the principles which governed in this study.

That the principles used are simple and broad in their scope is amply proved by the similarity of studies, based upon them, which have been submitted by Army engineers in New England, the Middle and South Atlantic States, the Northern and Central States and the Pacific coast. The study, as I have shown it, is a composite study of the Nation's network of transportation, made from many angles of consideration, all based on the world's greatest experience in transportation. It is offered by the War Department to all who are interested in the development of our Nation's transportation, as a piece of national transportation research and a willing contribution to American commerce by the United States Army.

IRON AND SEMI-STEEL

WROUGHT iron is made by the puddling process and is the purest variety of commercial iron, usually containing less than 0.08 carbon and approximately 1.00 per cent slag, the peculiar orientation of which is responsible for its remarkable resistance to corrosion and for its fibrous structure, allowing a large degree of plastic flow or movement within its crystal aggregate that makes it weak in compression. Wrought iron is very ductile and malleable, bending through an angle of 180 deg. or doubling flat on itself without breaking. It melts at a temperature of 1600 deg. cent. (2912 deg. fahr.) and is still sluggish and viscous at temperatures so high that it is not practical to cast it into molds.

Malleable iron is cast iron of a special chemical composition, melted in a reverberatory or air-furnace, and on rare occasions in a cupola, and then cast into molds of its final form. The resulting casting is entirely white or all carbon is present in the combined form as iron carbide, cementite, Fe_3C. Annealing in iron scale, Fe_3O_4, and sand packing at a temperature of from 760 to 925 deg. cent. (1400 to 1697 deg. fahr.) for a period of 40 to 60 hr. changes the carbide to the free amorphous carbon and ferrite, thereby rendering the casting malleable and very ductile at room temperatures.

Malleable iron is lower in carbon, silicon, sulphur, phosphorus and manganese than gray cast iron. It is, therefore, more viscous and must be cast at a higher temperature than the former; consequently it requires greater skill and care, on the part of the molder, to avoid misruns and excessive washing and scoring of the mold from the highly heated metal. Malleable-iron castings combine the advantages of ordinary gray-iron castings with respect to the ease of production and cost, with a ductility and strength approaching that of steel.

Cast iron differs markedly from wrought iron and steel, chemically as well as in physical characteristics. It has a coarse, crystalline grain structure, lacks toughness and is brittle at all temperatures below its melting point. The tensile-strength is not affected at temperatures below 1000 deg. fahr. but falls off quickly near the critical range and becomes very low at high temperatures. It melts at a low temperature, 2200 deg. fahr., and passes suddenly into a very fluid state and fills the molds well when cast.

Gray cast iron contains a large amount of graphitic carbon, appearing in an irregular elongated aggregate of crystalline carbon resembling curved flakes or plates imbedded in a matrix of ferrite and cementite. The percentage of free graphite or graphitic carbon in gray cast iron depends upon the percentage composition of the other chemical constituents of the iron, such as silicon, manganese, sulphur, phosphorus. Silicon more especially influences the separation of graphite on the cooling of the iron from the liquid to the solid. However, ordinary machinery iron contains approximately 3.00 per cent carbon and 0.50 per cent combined carbon.

Semi-steel is gray iron of such composition with regard to silicon and carbon as to give the highest possible strength in conjunction with the other properties and characteristics inherent in gray cast iron. Properties such as high compressive strength, low coefficient of expansion, rust-resisting qualities, low melting point, high abrasive resistance, great hardness, wearing properties and others are obtained by melting a mixture of foundry pig iron, gray iron scrap, and from 10 to 40 per cent of low-carbon steel-scrap in a cupola and casting the liquid iron into green-sand molds.—From an article by W. J. Merten in *Forging and Heat-Treating.*

The Coordination of the Motorbus and the Street Railway

By C. D. Emmons[1]

Cleveland Automotive Transportation Meeting Paper

THE author believes that, except for aerial navigation, whatever new forms of transportation may be developed must be auxiliaries to the rail lines, and that the problem is to bring about coordination between railroads and railways on the one hand and all remaining forms of transportation on the other. He concentrates upon coordinating motorbus and motor-truck service with rail service.

He reviews the attempts already made to displace the railways and substitute motor-vehicle service, quoting statements of fact and of opinion from the press, discusses the limitations of motorbus service and considers the factors of expense that apply to the motor vehicle when it becomes a common carrier. The elements of motor-vehicle operation, the necessity of educating the public to understand the conditions that control the cost of transportation, destructive competition and motorbuses as railway auxiliaries are treated also in some detail.

IN the first place, it is well recognized that no form of transportation has yet been devised that can take the place of the railroads for long-distance travel, in speed and comfort, and that of the electric railways for mass transportation. They unquestionably carry the greatest quantities of goods and the largest numbers of people at the lowest cost. Whatever new forms of transportation may be developed, with the possible exception of vehicles navigating the air, must be auxiliaries to the rail lines. I do not say this because of any prejudice favorable to railroads and the electric railways, but because this finding is a fact that has been amply demonstrated. The problem before everybody interested in transportation, therefore, is to bring about coordination between the railroads and railways on the one hand, and all other forms of transportation on the other. At this time we can leave out of consideration airplanes and airships, steamboats and canal transport, and concentrate our attention upon coordinating motorbus and motor-truck service with rail service.

A few years ago, when the electric railways were suffering from the effects of high wages, high costs of materials and depleted man power, there were those who thought that the motorbus or jitney could take the place of the established electric railways. Most automotive engineers are well aware of what happened in several communities. There was Des Moines, Iowa, for one example, and Bridgeport, Conn., for another. In both these cities the motor vehicles that were pressed into service when the electric railways were forced to stop operation failed to serve the public. I am not saying that motor vehicles properly designed for handling mass transportation and operated by an organization that has had adequate transportation experience, could not take care of the transit problems of a community satisfactorily, but I do say that no motor vehicle that has been designed so far can give the public the service that it has a right to expect, except at a rate of fare that would be very much greater than the rate charged by the electric railway for the same kind of service.

It is interesting to look back upon the experience of some of these cities where the attempt was made to displace the railways. In Bridgeport, Conn., the public felt so certain that jitneys and motorbuses could give it the service it wanted that the people refused to recognize the justice of any argument the electric railway might advance. Eventually the electric railway was compelled to stop serving the people. The city was without street-car service for several weeks. A Bridgeport newspaper that had been antagonistic to the electric railway in reviewing this situation recently said that:

> The substitute motor transportation cost the merchants hundreds of thousands of dollars' worth of business in a few weeks' time simply because the people from outlying sections of the city were not able to get into the city for trade. There were thousands of people who would not travel at all, finding it better to put up with the inconvenience of staying at home than to submit themselves to the danger, annoyance and confusion of crowded and unregulated jitney travel.

This is a mild statement of the facts. Bridgeport, like Des Moines, recognizes that the backbone of its transportation system is the electric railway. Nevertheless, it recognizes the value of the motor vehicle. The same newspaper also said:

> The motorbus properly operated has come not only to stay as a transportation factor, but to play an increasing role in the development of new territory. The right system would include a combination of both kinds of service, each operating in the field to which it is best suited, *but the service should be properly coordinated under one management.* There is but one way to attain such a combination in Bridgeport. That is for the electric-railway company to acquire the present motor-vehicle lines and operate both trolleys and jitneys under the supervision of the Public Utilities Commission.

In an article entitled Riding on Rubber[2], Edward Hungerford makes the following statement:

> The proponents of the street car in city traffic as against the motorbus are apt to make much of the supposed inability of the latter vehicle to handle great numbers of people within a reasonably short space of time. Yet nightly in crowded New York more than 180 motor coaches an hour are operated in a single direction, or on a headway of something less than 20 sec. Each of these double-decked buses seats 51 persons, standees are never permitted, which means that in the course of an hour close to 10,000 passengers are picked up and carried north through New York's homebound rush in the evening.

This statement is not entirely accurate. During a check made on a typical week day in March, at Fifth Avenue and 43rd Street, New York City, between the hours of 4:35 and 6:05 p. m., or 1½ hr., 205 buses were operated northbound. This is an average headway of

[1] President, American Electric Railway Association, New York City; also president United Railways & Electric Co. of Baltimore, Baltimore.

[2] See *Saturday Evening Post*, March 24, 1923, p. 44.

26 1/3 sec. During the heaviest 5-min. period, an interval of 17 sec. was maintained. During the heaviest 60 min. of travel, the average headway was 24.2 sec., or 149 buses. For the entire period, the 205 buses carried 7189 passengers.

Now compare this with other methods of mass transportation. The same number of people could be transported in 7 subway trains of 10 cars each, with approximately 100 people per car and, at the minimum headway operated in the subway of 1 min. and 48 sec., they would have completed the hauling in 12 min. and 36 sec. This, of course, is far less than is carried in these trains during the rush-hours. The trains evenly spaced, would operate under a headway of about 13 min. The speed at which the people would be transported to their destinations, of course, would be very much higher. Forty-five modern two-car surface trains could have carried this entire number of people and, operating on a 45-sec. headway, would have handled them in less than 34 min., or, if spread over the 1½-hr. period, on a 2-min. headway.

In the instances I have quoted, some standing passengers are provided, but one can easily figure that the loads proposed in the subway trains and in the two-car surface-trains are much less than is usually handled during the rush-hour period. If only seated passengers were to be handled in subway cars, obviously many more seats could be provided in the present cars and still leave sufficient room for passageways.

Limitations of Motorbus Service

One point that must not be overlooked when discussing the Fifth Avenue bus service, or any similar service in this Country, is that these services are all supplementary and in no case do they handle the mass or bulk of the passengers who want to ride. In other words, do not let us blind ourselves to the fact that, so far, in no large city, and I do not except London in this respect, have motorbuses alone been able to handle the mass of passengers. In all cases, where conditions approaching the American rush-hour obtain, rapid-transit facilities or the larger capacity surface-cars are needed.

There is no conflict between the electric railways and the motor-vehicle industry. Instead there is the heartiest cooperation. There are many electric railways in the United States that are using motor vehicles in connection with their transportation service. On the other hand, there are many railways that are suffering from parasitic competition from unregulated motor vehicles. These railways serve communities that have not yet learned that these two forms of transportation cannot operate in competition with each other without one or the other going broke. It is for the people themselves to decide whether they wish to keep the railways or the motor vehicles. I think all sensible men will say that if the motor vehicle will serve a community better and at a lower rate of fare than can be offered by an electric railway, then by all means junk the railway. The fact, however, is that except in very small communities the railway is ever so much cheaper to operate than the motor vehicle.

In the illuminating, almost prophetic address by Vice-President Elisha Lee of the Pennsylvania Railroad Co. before the Society at the 1923 Annual Dinner, entitled The Motor Truck and Our Railways[3], I was struck with his remarks on coordination, not competition, and on the needs of the citizenry of this Country for the cooperative services of railroads and motor vehicles. His speech will reward re-reading and study.

This problem of competition between railways and motor vehicles has become very acute in some places. Massachusetts has paid particular attention to it, as have Pennsylvania, Maryland, Connecticut, Rhode Island and other States. The Massachusetts Department of Public Utilities, in January, 1923, submitted a special report to the Legislature of that State in which it discussed this problem very extensively. I will quote a paragraph or two from its report. It says:

> The motor truck has, of course, had very little effect upon the street railways. The jitney and private automobile, however, have had an enormous effect upon them which is so obvious and so well known that it needs no recital. The result has been that about 400 miles of street-railway lines in this commonwealth have been abandoned. Interurban traffic on street railways in many communities is moribund; semi-urban traffic on them has been seriously injured, and even metropolitan traffic in the heart of Boston itself has been injuriously affected. Besides that, and this fact is not perhaps so generally recognized, the automobile has become the biggest electric-railway hazard and costs street railways large sums of money in safety measures and in suits. It also affects injuriously street railways in numerous other ways.
>
> Constant attempts are being made to force large expenses on street railways for the benefit of automobile traffic. It was, for example, suggested a short while ago that the subway edifice in Harvard Square, Cambridge, should be removed at a substantial cost to the railway to make that square safer, while a rerouting of the automobiles during rush-hours would have accomplished the purpose better. A number of citizens have just appeared before this Department urging upon us the abolition of one-man cars in Malden, partly because of congestion in certain parts of Malden due to these cars, and to the promiscuous and unrestricted parking of automobiles. These two cases are typical of many that are constantly arising where the thought of restricting automobile traffic appears to be regarded as entirely out of the realm of possibility and the contention is that street railways, and this, of course, means the riders upon them, should be subjected to large additional burdens to prevent inconveniencing the automobilists in the slightest degree. This attitude, and the pressure which results from it, is costly to the street railways and hence to their patrons.

The Massachusetts Department of Public Utilities also points out the effect of automobile traffic upon the State highways. It says:

> It is very doubtful whether a roadbed has yet been developed which will stand for any substantial length of time the constant wear and tear of this heavy traffic. It is, at any rate, clear that our older highways have had to be, and will continue to have to be rebuilt on a far more expensive scale, and that both these and the newer highways are going to cost a sum for maintenance which would have been regarded as extravagance a few years ago. But this is not all. Those interested in motor-truck transportation have recently pointed out that it will be necessary to widen some of our roads to 30 ft. to take care of their traffic and that, in general, special roads for trucks must be built, with a width of probably 20 ft. It is not surprising that the advocates of motor trucks take this position. Why should they not, in view of the fact that these fine highways will be a great asset to them and that they will have to pay nothing for them worth talking of beyond what the ordinary taxpayer does? We believe it is necessary to face the fact that if the commonwealth continues its present policy in this regard,

[3] See The Journal, February, 1923, p. 151.

the construction and maintenance of state highways for motor trucks will cost an ever-increasing and before long a staggering amount. The same thing exactly is happening in the case of bridges, as we pointed out before, and in the case of county and city and town roads.

These words by the Massachusetts commission, which states explicitly that it is not prejudiced against motor vehicles but of which, it says, "We recognize that the automobile, both freight and passenger, is a useful appliance for the purposes of society," are worth pondering. The commission recommends to the Massachusetts Legislature that a board be created to consider among other things the following: First, proper compensation for the use of highways and bridges by motor vehicles. Second, the creation of areas and congested districts from which motor vehicles would be excluded wholly or partially. Third, the subjection of operators of motor trucks for hire to the jurisdiction of the Department of Public Utilities to the same extent and in the same manner as other well-recognized common carriers.

Motor Vehicles as Common Carriers

It almost universally develops that when the motor-vehicle common-carrier is subjected to the same burdens of taxation and to the same regulations that apply to the electric railways, they find it impossible to operate successfully. You are well aware that electric railways in many states are required to carry many extraneous burdens. They have to pay for the paving between the rails and for a distance outside their rails; they have to pay for watering streets, for snow removal; they pay a percentage of their gross income, whether they have any net income or not, in taxes to the state; they pay in many communities a tax on their income to the community; they pay franchise taxes, license fees and various other charges that put a very heavy load upon them.

The motor vehicle that is competing with them, in many communities, has free use of the paving for which the electric railway pays. In many states motor vehicles have not yet been classified as common carriers; there is no regulation of the rates of fare or charges for carrying freight; in many places they are not under bond, so that if a passenger becomes involved in an accident he has but slight chance to recover damages. They do not pay a percentage of their gross income to the state or communities; they do not have to help water the streets. Put upon the motor vehicle the same burden that the railway carries and fares that will permit successful competition with the railways become out of the question.

Perhaps these facts had something to do with the statement of Alfred Reeves, general manager of the National Automobile Chamber of Commerce, in a recent address. He said:

> Bus and truck lines have not all been successful generally because of mismanagement or because of routes that furnish insufficient return. All this means that the railroad men are the proper ones to take charge of bus and truck operations, making them feeders to the trolleys and steam lines.
>
> The motor industry is anxious to cooperate in every way that will make for each department of transportation finding its proper place, and this means efficiently serving the public.

Mr. Reeves' statement is further borne out by the recent reports of the Motor Vehicle Conference Committee on the Regulation of Motor Vehicles, the reports being almost in complete harmony with the attitude of the electric railways.

The automotive industry must realize that it cannot foster a service that engages in ruinous competition with rail lines, whether they be steam or electric. I venture to say that there are not enough motor trucks in the United States to bring to your automobile factories the raw materials that are necessary for the construction of motor vehicles. Nor are there streets wide enough, nor automobiles enough in any community, to carry the employes of your factories to and from work as expeditiously and cheaply as they are carried by the electric cars. These facts are self-evident and the National Automobile Chamber of Commerce takes the only proper step possible when it stands for coordination of motor vehicle and rail service. For example, a recent traffic survey in the City of Baltimore, Md., of the travel into and out of the business area showed that, while the automobile comprised 73 per cent of the total movements and the street cars only 27 per cent, the street cars actually accommodated almost 89 per cent of the total travel, while the automobile only accommodated about 11 per cent, disregarding the very small percentage of horse-drawn vehicles.

At the last Convention of the American Electric-Railway Association in Chicago in October, 1922, there was unanimously adopted a report by the Committee on Trackless Transportation in which the following statement was made:

> The basic transportation service in any community is and will be furnished upon rails. Trackless service will be found supplementing, but not competing with, that of the electric railway. The bus may be considered an additional equipment for the street railway. If the service of both means of transportation are coordinated, the net return of each will be reflected in the net return of the electric railway. New capital is annually required in the operation of a street railway. Part of this new capital may well be used in the development of trackless service in the field above mentioned.
>
> The possibilities of development of transportation with railless vehicles should interest the industry greatly and your committee feels that the study of the development in the design and construction of railless vehicles and their adaptability for highway transportation should be carried on further by a committee of your association.

You will see from this that the electric-railway industry is on record for coordination of motor vehicles and railways and it is most gratifying to find the National Automobile Chamber of Commerce adopting the same attitude. Working together, we are sure to solve the problems that beset us.

Motor-Vehicle Operation

There is a Committee of the American Electric Railway Transportation and Traffic Association that devotes its entire time to the study of motor-vehicle operation. It is made up of men who have spent practically their entire lives in the transportation business. They know what is necessary in any vehicle for economical and satisfactory transportation. The assistance that this committee can render and will render you men who are spending your time designing vehicles and engines will be very great. The transportation industry no longer will take any old kind of bus body put upon a standard truck chassis. The vehicle must be designed for the kind of service in which it is to be used, and let me say that we have found the motor-vehicle builders very willing to adopt suggestions that we have made. As I said before, there is no conflict between us, we are working together in complete harmony.

It is in this field especially, it seems to me, that the Society of Automotive Engineers comes into play. You are particularly interested in, and should be the ones to solve the needs from a design standpoint of automotive vehicles. The operating men, who are handling the public, are, in general, the ones best able to say what is needed to furnish to the public the most satisfactory character of vehicle for transportation, and it is the duty of the engineers to incorporate these needs into actual designs.

The question of light weight and economical operation are of particular importance from the standpoint of the financial returns to the operator. In connection with the need for lightness, there is not only less cost of operation and maintenance, but it lessens the wear on the roads and, in a number of cases, because of the tax laws on the books, there is a particular demand for light-weight vehicles. In Maryland, for instance, there is a tax of 1/6 cent per seat-mile for vehicles weighing more than 8500 lb.; the tax between 7000 and 8500 lb. being 1/15 cent per seat-mile, and you can easily imagine why we want a light automotive vehicle in Maryland, when there is an increase of almost 200 per cent in the tax basis the minute you go over 8500 lb.

The comfort and convenience of passengers is a very necessary factor in design. The appearance of the car is another thing that has a marked effect on public sentiment and involves, of course, in addition to the initial design, proper upkeep. Convenience in handling by chauffeur operator and easy riding qualities making for comfort are of great importance. The question of designing automotive vehicles with special reference to safety features is another side that must always be kept in mind; adequate lighting; ease and rapidity of acceleration; low steps and many additional details of construction, all of which bear upon the financial return to be expected; the comfort of passengers and the public-relation side of operation, which last is most important. You will see, therefore, from what I have just outlined in rather a sketchy fashion, that the automotive engineers need to cooperate most closely with the operators in order that the most satisfactory type of automotive vehicle may be evolved.

Cost of Transportation

It seems to me that before we can have coordinated transportation-service we must have a public educated to understand the cost of transportation. In the past, the troubles of the railroads and the electric railways have been due to public ignorance of railroad and railway conditions. An individual who himself earned 75 to 100 per cent more wages than he received in 1914 and who paid, without a murmur, 75 to 100 per cent more for his clothing, fuel and other necessaries of life, would wave his arms in the air and wax wrathy when the railroad or the electric railway was compelled to increase its freight or passenger rates. This individual was blind and deaf to the fact that everybody working for the railways had had his pay raised; that every bit of steel, copper, wood and materials of whatever nature, cost more than they did in 1914, largely because of labor costs in their manufacture, and that there was no possibility of the transportation companies getting the money with which to pay higher wages and increased costs of materials except through the charges made for carrying freight and passengers.

There are still some communities where the people will not recognize the fact. In some of them they are deluded by demagogic politicians and a certain type of sensational newspaper that seeks profits at the expense of the public welfare.

In Detroit, where in May, 1922, the city took over the electric-railway lines formerly operated by a private company, there is now indignation on the part of the city councilmen because several hundred jitneys are competing with the city-owned trolley cars. An ordinance was passed last fall, designed to prevent jitney operation, but an injunction was obtained recently that temporarily nullified the ordinance. Whether this injunction has been vacated I am not aware, but it is a most interesting fact that when the private company operated the electric cars in Detroit the city seemingly did everything within its power to encourage jitney competition. Now that the city owns the railways and is putting on buses of its own, the city fathers recognize the injustice and the uneconomic conditions that accompany competitive transportation services in a given community.

Destructive Competition

Connecticut and Rhode Island have come through rather strenuous experiences with destructive transportation competition. In Connecticut, many towns that formerly enjoyed electric-railway service are now without it because of the dismantling of the railway that formerly served them. Three of the four electric-railway companies in that State are in the hands of receivers. Not until this condition came about did the people awaken to the situation that confronted them. Then the Legislature enacted laws making jitneys common carriers and subjecting them to regulation by the Public Utilities Commission. The Rhode Island Legislature enacted similar laws. The Massachusetts Department of Public Utilities recommends similar legislation in that State. Pennsylvania and Maryland had taken action before the New England states acted. In the Middle West, progress has been slow and interurban railways have suffered very severely. Indications are now that the people are awakening to a realization of the misfortune that would impend were these railways compelled to cease operating and relief is confidently expected.

Where electric railways have placed motor vehicles in operation, they have for the most part been successful. You realize, of course, that every time a real-estate operator starts to develop a tract remote from an electric-railway line, he and those to whom he has sold lots frame a petition to the railway or to the community authorities, demanding transportation service. If he does not get it, he becomes indignant. What he is really asking is that the railway company should, without charge to him, provide a service that will be operated at a loss but that will increase the value of his property. The unfairness of this attitude is obvious.

Real-estate owners are well aware that a gas company or an electric-light company will not extend mains and power lines into a new tract unless it is guaranteed a certain amount of business or unless there is a sufficient number of property owners who will take sufficient service to make a return upon the investment certain. The soundness of the gas company's and the electric light-company's attitude is well recognized. How strange then that, when the same favor is asked of an electric-railway company and it is not immediately granted, the property owners feel that they are not being accorded just treatment!

In Cleveland there have been situations identical with such as I have mentioned and the railway company, with

(*Concluded on p.* 464)

English Cartage-Practice a Standard for Our Railway-Terminal Trucking

By F. C. Horner[1]

Cleveland Automotive Transportation Meeting Paper *Illustrated with* Photographs

THE author discusses the factors that must be considered in solving the transportation problems and then describes the operation of the English-railway cartage-system in some detail under the two main divisions of delivery and collection. An important feature of the system is that of the control afforded by locating a controller, or dispatcher, in a central office and holding him responsible for the movements of the carmen, or drivers. The details of this control are explained.

The field for the motor truck in railroad-terminal service is outlined and a presentation is made of the merits and demerits of unit containers, together with an illustrated description of the English "flats," or demountable bodies.

Other subjects treated include cartage costs, tonnage hauled, unified control of cartage and expressions of opinion quoted from numerous English trade organizations.

SINCE the expense and delay that now exist will eventually prove disastrous to both the railways and the traders unless we find a solution for the problem of the cartage of the miscellaneous-goods traffic at our railway terminals, I will point out some of the evils of our present methods of collecting and delivering miscellaneous goods at the railway terminals, and then describe how the English perform this kind of service. In this way I hope to make a clear enough comparison of the two systems to enable you to decide what the proper course is for us to pursue in finding the solution of this problem.

Many are perhaps unfamiliar with English transportation terms, so I will explain that "miscellaneous goods" is the English term for less-than-carload (l. c. l.) freight; "cartage" is substituted for trucking, "trader" for both consignee and consignor, "van" for horse-drawn vehicle and "carman" for driver or chauffeur. I will use the English terms in describing their methods as, in most cases, they make for both brevity and expressiveness.

Transportation-Problem Factors

I will not quote what the motor-truck interests say about this subject of railway cartage, but later will cite what some of the railroad executives have said, as examples of the importance the railroads attach to the problem. I wish to make it very clear that, in my opinion, the wasteful and chaotic methods of collecting and delivering the miscellaneous goods at the railway terminals in our cities is just as much the fault of the traders and the cartage companies as it is of the railways themselves. Unless all three agencies are willing to give and take and to cooperate in every sense of the word, existing conditions will never be remedied, but will go on getting worse until eventually it will result in seriously retarding the development and prosperity of the Country and this will come sooner than some may think.

In the first place, it certainly seems reasonable to say that the railroads and all other transport undertakings should be run on the same plan as any sound business undertaking. In other words, the transport companies should be permitted to earn a maximum return on their investment consistent with an efficient and economical transportation service. Referring to the railroads in particular, as they are the principal agencies concerned, it seems only fair to permit them to accumulate a surplus in good years to carry them over bad years. Every business enterprise is allowed to profit by the increased business in "fat" years and, through proper direction, be prepared to carry over during the "lean" years sufficient funds to fulfill the obligations any stable organization must have to retain the confidence and support of its shareholders and of the public. Surely, the railroads should be entitled to the same consideration, especially when they play such a vital part in the life of every country, particularly in this Country of ours where the distances are so great and adequate transportation facilities so necessary to our progress. Many will say that such policies are impossible, that they would endanger the whole business structure of the Country because there must be cheap transportation regardless of everything, and the only way to insure it is by keeping the "lid" on the railroads when it comes to making a profit by transporting the people and goods of the Country.

The best way to keep down the cost of everything we purchase is to reduce railroad freight-rates and, in passing, I ask whether the public benefits to anything like the same extent when the rates are reduced as it pays for the increased cost of goods when the rates are raised. My reply to such arguments is that, without sufficient funds, the railroads cannot furnish adequate, efficient and economical transportation service for this Country or any other. This is the condition of affairs we are now rapidly approaching; in the case of many railroads, we already have reached it.

It is a well-known fact that many of our railroads have been mismanaged in the past and, for this reason, much unwise regulation to control them has been brought about. Moreover, when we consider for instance that, according to President Loree of the Delaware and Hudson Railroad, in an average 14-day cycle for a freight car it moves only 1¼ days, it is apparent that the efficiency with which our railroads are operated leaves much to be desired. This is not a paper on railroad economics, but in order that we may take a broad outlook of the matter, we must first study it from all sides. I wish to point out some of the things the men in the automotive industry can do to help the railroads and by so doing, to help themselves as well; to work out a really efficient and economical transportation service that will enable the railroads and all other transport agencies to supply transportation facilities adequate to our needs, and at the same time make sufficient profit to attract the required capital to carry on with.

[1] M.S.A.E.—Consulting engineer, General Motors Corporation, New York City.

The greatest sources of waste in our present transportation system are, first, where the railway stops and cartage begins; and, second, in the short-haul field. Compare the rail charges on a consignment of l.c.l. freight with the average cost of collecting and delivering the freight at both ends. Even on those carload shipments where the goods must be carted at both ends, the cartage cost, due to delays at terminals congested with freight waiting to be cleared, and inefficient cartage methods, is usually greatly in excess of the rail charges; or, at least, the proportion of the cartage cost to the rail charges, distance considered, is entirely out of the realm of economy. Naturally, this condition has a disastrous effect on the railroads. Congested terminals mean that the equipment is tied up and the whole system is thrown out of gear all along the line. The extent to which this affects the business of the Country can be measured by the volume of traffic to be dealt with. If the traffic is heavy, the conditions we had in 1919 and 1920, of embargoes and terminals choked with traffic, will result. But even with normal traffic and no embargoes, the economic waste and delay costs enough in 1 year to make it more than worthwhile to grapple with the problem and solve it. We can solve it, once we realize two things; first, that there is such a problem and, second, that we can save money by finding a proper solution for it.

The best way of attacking this problem is, in my opinion, as follows: There are four major classes of goods to be transported commonly known as carload, less than carload, express and parcel post. The first can be eliminated for the moment. The remaining three, then, are the cause of most of our transportation waste, but especially the first of these. Here is where there is the greatest room for improvement, in the cartage of l.c.l. freight between the railway terminal and the store door. All are more or less familiar with the confusion and loss of effectiveness that result from the absolute lack of any systematic method of railway-terminal cartage. You also know that, due to the absence of scientific loading, routing and scheduling methods, it is common practice to have 5-ton motor-trucks leaving terminals and store doors with only a few hundred pounds of goods, not to mention the degree to which this sort of wasteful transportation prevails with smaller sizes of motor trucks and horse-drawn vehicles.

Aside from the need for reform in this particular field of transport alone, think of the economic waste involved in the transport of l. c. l., express and parcel-post traffic combined. Performing practically the same service, at least so far as deliveries at destination points are concerned, the result is that a trader frequently will have three different vehicles at his door; one, say with 1000 lb. of freight, another with 200 lb. of express, and a third with a 10-lb. parcel-post package, all three carted from the same terminal but in three separate partially loaded vehicles. There is nothing economical or efficient in such methods, and no reason for such waste and duplication of effort. The railroad side of this picture shows the same duplication of effort with a consequent waste of equipment prevailing. We have the freight car, the express car and the parcel-post mail-car, all going to the same place, when the contents of all three could be carried in the freight car alone at an enormous saving to the railroads in equipment and labor. In short, what we need to do is to get greater load-efficiency out of our transportation equipment, on both road and rail, and load to capacity. The only way to do this is through the coordination of all transportation agencies. Each must harmonize with the other.

We must acknowledge that the kind of transportation I have outlined is far from constituting harmony and coordination of effort. To haul goods 250 miles overnight by rail and take the same amount of time, or longer and usually at greater cost, to transport those goods from the railway terminal to the merchant's store door, 2 or 3 miles away, is a sad reflection on our business sense.

An executive of one of the largest railroads in this Country stated recently that between 400 and 500 cars could be released per day in one city alone if his railroad could get rid of the intra-city haul. Think what such a saving would mean to that railroad and to the merchants of the Country in one year alone; it would make more than 150,000 cars available per annum for other work. Another railway executive said that the use of the present equipment for our railroads would be increased threefold by the elimination of terminal waste.

With regard to the transportation problem we have to solve and the advantage of solving it, I will quote what two of our railroad executives say in reference to this matter. W. H. Lyford, vice-president of the Chicago & Eastern Illinois Railway Co., said in a paper delivered before the National Highway Conference at Washington, in October, 1922:

> The most important field for cooperation between the railway and the truck is offered by collection and delivery of l.c.l. freight in large cities.
>
> Combined l.c.l. freight of all railways reaching a city could be collected and delivered by a properly equipped single trucking-organization, working in full cooperation with the railways, at less cost than is now paid by the traders in that city for their cartage, and still yield a valuable profit to the trucking organization.

Elisha Lee, vice-president of the Pennsylvania Railroad Co., said in his address on The Motor Truck and Our Railroads:[2]

> It seems to me that one of the most important opportunities for useful and successful coordination of motor and rail facilities may be expected to lie in organizing smooth-working freight pick-up and delivery motor services in the larger cities, for the less than carload traffic, to be operated in connection with inter-city hauls by rail. Such an arrangement would extend the scope of rail transportation by making it a really complete service from the premises of the shipper to the premises of the consignee. It would allot to each transportation agency employed the portion of the service which each is pre-eminently fitted to perform; to the truck the terminal work and to the railroad the line haul. This subject is of vital importance to the railroads, their patrons and the makers of motor vehicles, alike. If such a service could be worked out for the larger centers of the Country generally, it would constitute one of the most momentous advances ever made in the handling of railroad traffic, and create an economically sound market for the product of the motor-truck makers.
>
> In approaching this question it may be noted that the tendency usually is to dwell largely upon the possibilities of reducing the cost of distribution through the establishment of such a system of store-door collection and delivery, in the sense of making possible a structure of through-rates which would be lower than the combination of the existing rail-rates and the present costs of collection and delivery at each end. It may be doubted whether that is really the best selling point upon which the automotive interests can focus attention, or whether it is actually capable of immediate realization. It must be remembered that to inaugurate

[2] See THE JOURNAL, February, 1923, p. 152.

such a service as we are talking about, it will be necessary to enlist the aid of considerable new capital. A service of the character contemplated would certainly be a vast improvement over the haphazard facilities for collection and delivery now usually at the disposal of shippers and consignees who do not have their own trucks. It would constitute a notable addition to the present service and should be worth a fair and reasonable price. It is difficult to see upon what other basis the needed capital can be attracted.

In convenience and speed such a service would lie midway between the present ordinary freight and the express. It would be substantially a semi-express service, affording complete through transportation, rendered by a combination of motor truck and freight train instead of by a combination of truck and passenger train. The aggregate charges would of necessity have to be adjusted in proper recognition of the character of the service, always bearing in mind that new capital must be attracted if trucks are to be purchased and operated. There would be many economies outside of the rates themselves. Among them may be enumerated the greater dependability of service; the reduction of losses in transit; lower insurance rates; greater ease in making shipping arrangements and paying bills; and a reduction in the time goods are on the way, which would amount to a saving of interest on idle capital. The shortening of the time in transit would also permit the carrying-on of business with smaller stocks, thus in another way reducing capital charges.

In other directions such a system of collection and delivery would effect many savings which, although difficult to measure exactly, would be nevertheless real. Among them may be mentioned the more efficient use of the public thoroughfares, lessening the losses and delays now incident to the street congestion and crowding that are so marked under the present totally unorganized trucking methods in general use.

Since my return from Europe, the picture I have got of this situation is that the railway men, whatever their record has been during the past, are now more than willing to cooperate with the traders and the public to work out some plan that will be satisfactory to everyone. Let us hope that our lawmakers will also cooperate and make it possible for the railways to furnish constructive assistance in this matter, unhampered by restrictive regulations. The foregoing shows that an efficient system for the collection and delivery of miscellaneous-goods traffic at railway terminals is of vital importance to the success of the railroads as well as to the traders and the public.

Delay and Excessive Cartage Cost

To show clearly what a large factor cartage is in the cost and the time of transporting miscellaneous goods in our large cities, I will relate an experience of my own. My home is in New York City and, having purchased two beds in Baltimore, I had them properly crated and shipped to me by freight. Five days after the beds were shipped, I received a notice from the railroad company that the beds were at the Harlem River Freight Station and that they must be removed within 48 hr. Upon telephoning the freight station, I was referred to a "reliable" truckman, who agreed to deliver the beds at my house. This he eventually did, but not within the time limit of 48 hr.; so, I was forced to pay 50 cents for storage charges, and the cartage charge on the two crates of 130 lb. each was $4. The freight charge from Baltimore to New York City, about 200 miles, was $2.13 and the cartage from the freight depot to my house, about 2¼ miles, was $4. When I protested both the cartage and the storage charge, the driver of the motor truck invited me to go and see what a difficult job it was to collect freight at that station.

After finding out the tonnage he moved per day, I am satisfied that, if there was to be a fair profit for his company, the charge made was not excessive. This cartage company is an organized company that has been in the business for some time, but from what I learned then and since the trouble is largely due to the general lack of system at such freight stations and in cartage methods, and this case is a typical example of the waste that prevails in this field of transport. The load efficiency of that cartage company's trucks, including return loads, was about 30 per cent.

The foregoing information should make us realize the necessity for our help and active participation in the accomplishment of something that will benefit all of us, whether we be traders, railway men or motor-truck operators, poets or farmers; and I will now relate some of the essential things about English-railway cartage-methods for the collection and delivery of miscellaneous-goods traffic, as I am convinced that their plan contains the principal elements of a system that perhaps would not be a "cure-all" for us, but would, at least, be a vast improvement over our present disorganized practice.

The English-Railway Cartage-System

The term miscellaneous goods is used by the English railways to cover the class of freight that we usually term l. c. l.; in other words, the freight composed of small consignments, not the carload or large shipments, the so-called "store-door delivery" variety which, in England, is composed of consignments of about 300 lb. or less each. The details of the cartage and station workings constitute such a complex subject that it is only possible to give an outline of the system at this time. Therefore, I will discuss the subject only under the two main headings of delivery and collection. The delivery of goods begins at the time the car door is opened, and ends at the time the cartage vehicle leaves the trader's door. The major steps between those two points are best divided as follows:

(1) Unloading and checking of goods from cars to platform or vans

(2) Barrowing of goods to van-loading sections or warehouse

(3) Loading and checking of goods onto cartage vehicles in district and street order

(4) Loaded vehicles removed from sheds, and either parked by van setters or removed by carmen; accompanied by a pass, over scales and out into town for delivery

The first step in item (1) is controlled by the checker, and his guide is the invoice of the contents of the car. The work of marking the invoices is a big subject, and one that cannot be thoroughly covered at this time. It is sufficient to explain that when the invoice reaches the checker at the car door, it contains the following information pertaining to the cartage side of each consignment: (*a*), whether traffic is "delivered," or on a "wait order"; (*b*),the name of the street; (*c*), the postal area, including the area number; (*d*), the locality; and (*e*), the district number or mark. Regarding the information shown on each invoice, it should be noted that the "district markers," the men who mark the invoices, must be accurate. Local knowledge and experience gained by constant repetition of company and street names enable the marking to proceed like clockwork; in fact, in course of time, the staff becomes independent of the street lists for the most part.

The checker furnished with the invoices duly marked, instructs the "barrower" to what point he is to take the packages, whether to a "delivered" berth or to a "wait-order" berth. The "barrower" in time becomes so familiar with this work of item (2) that he has only to be given the name of the consignee to know where the goods should be placed. Many of these men have been with the same railway all their lives, and a large part of the time on one particular job.

Item (3) constitutes one of the most important steps of all. The van loader has a "delivery sheet" for each consignment of goods. The delivery sheet is made out from the invoice, and is practically an exact copy of the entries on the invoice. The "single-entry delivery sheet" is used very generally by all English railways now and, as the name signifies, it deals with one consignment only. This document eventually becomes the railway company's receipt for the goods, and is the "Bible" of the carman or truck driver, because his delivery sheets cover all of the goods on his van; each sheet is charged to him when he leaves the station and must be accounted for before he checks off at night.

The van loader should possess the two important attributes of having a thorough knowledge of the traders and the streets and being skillful in stowing goods with the object of securing immunity from damage. The first qualification should insure that the goods are positioned so as to avoid any unnecessary travel on the delivery rounds and the overhauling of loads in the street en route; the second should obviate damage to the goods and also personal injury through street accidents.

We can consider that the van is now loaded and ready for the carman. The vans that are parked after being loaded need not be described at this time. The carman must first get his delivery sheets, and from them find out the number of his van. Carmen usually have the same horse or horses every day or the same motor truck, but may have any one of several hundred vans. As soon as the carman obtains his delivery sheets from the cartage office, he is off to his district to deliver the goods, after presenting his gate pass to the policeman at the gate.

The subject of districts is covered more in detail in describing the cartage-control system of the Midland Railway. It should be explained, however, that there can be no hard-and-fast rule as to the size and the shape of the districts. Thus, where the traffic ordinarily is sufficient for one vehicle per day only, a district carman will take a fairly large radius; on the other hand, where there are many firms in close proximity to one another, several districts may be comprised within a small compass. This means that exhaustive tests will be necessary to determine the most suitable divisions, and here is where the English postal-area map is so valuable in laying-out the districts. In most cases, the districts are based on collection stops, and the carman is given a load into his particular collection district.

In following the carman through, we find that he makes his deliveries in the order in which he can save the most time and travel the shortest distance, but all the time bearing in mind his collections that are to be made that day. He usually finishes one or more loads of deliveries by 12:00 noon and starts on his collection rounds after lunch.

It should be noted here that the bulk of the miscellaneous-goods traffic on English railways is delivered to the consignees before 12:00 noon every day, and it is common practice to give 24-hr. service for this traffic to places 200 miles distant, and often farther than that on certain classes of traffic. Think of it; the "Bradford traffic," woolen goods largely, is picked-up say before 5:00 p. m. today and is invariably delivered in the "Wood-Street Zone" in London by 9:30 a. m. tomorrow; and Bradford is 230 odd miles from London. This is not a special performance. The English trader expects and demands this kind of service, and the railway-goods agent has a complaint to deal with very quickly if the goods are late in arriving at the trader's store door. One may ask, how it is possible to give such service. It all hinges on the "eye-of-the-needle" link in the chain of transporting the goods; that is, the freight-station handling-and-cartage system. Every railway man and many of the prominent traders with whom I talked about this matter were emphatic in stating that the traffic could not be handled expeditiously if the traders did their own cartage. The stations would have to be double their present size and, even were that possible, it would be a very doubtful proposition.

The collection of the goods from the trader's, or consignor's, door can be divided into four operations, and are practically just the reverse of the delivery workings; (*a*) traffic carted into the station, accompanied by "consignment notes"; (*b*) van loads backed to shed platforms or cars; (*c*) the unloading of the van loads and the weighing of consignments; and (*d*) the barrowing of goods to the car side. The districts assigned to the regular "district carman," or "roundsman" as he is sometimes called, are based on the collection stops in a given area or district. Each district carman has a list of the regular stops in his district; some are daily, some every other day and the like. In addition, he may have several special calls to make within his district. Special or extra deliveries and collections are usually taken care of by "unattached" or "odd" carmen. Here is where the "cartage controller" comes into the picture.

Cartage-Control System

The Midland Railway has, in London, the most scientific cartage-control system of which I know. The essential features of the system are as follows: St. Pancras and Somers Town are the two main London goods stations of the Midland Railway. In addition, they also have several sub-stations with rail connections and some depots and receiving offices, neither of which have rail connections and are used largely to receive traffic from the traders located in this vicinity. This traffic is consolidated into loads for the main outwards goods-station, there to be loaded into cars and dispatched to the consignee. London is divided into what are known as postal areas, such as N. W. 1, E. C. 4, S. W. 1 and so on. This was done by the Post Office Department to expedite the delivery of mail, and this postal area or zone map is used by every railway and road-transport firm engaged in collection and delivery service in London. Using the postal-area map as a basis, the Midland Railway has divided London into ½-mile squares based on the collection stops required. Each carman is allotted a district covering one or more of these ½-mile squares; he receives a district number by which he is known, and all the various documents, delivery sheets and the like that he deals with bear his district number.

Taking the delivery of the goods from the goods station to the trader's door first, the written instructions to the loading staff are to follow the lists prepared for them showing the principal streets in each postal area, and giving the number of the district carman responsible for the collection of traffic in each street. So far as possible, the same carman performs both delivery and collection work in his particular area, but where this is

not possible to arrange, he delivers in some closely adjacent area, and the loaders must load the vans accordingly. It is a rule that the arrangements made must not be such as will prevent the district carmen from getting onto their collection work at the scheduled time. All the regular collection stops are made on a schedule-time plan. When a carman leaves with his first load of deliveries in the morning, he knows whether he is to return for another load, to report to the controller's office or to perform either his regular or some special work. In most cases, the district carmen report to their call office after finishing their deliveries. Each call office is supplied with schedules of the district carmen working in the vicinity. These schedules show all details of the carman's work, together with the streets and the houses covered by each. The following rules explain the method by which the cartage controller is kept informed as to the movements of all carmen:

(1) Any orders of a miscellaneous character received at a call office, either through post or by telephone, must be numbered with the district number and handed to the carman when he calls

(2) Full-load collection-orders received by the receiving offices and depots must be telephoned to the control office at Somers Town

(3) Orders received by the receiving offices and depots, subsequent to departure of the district carman, must be telephoned to the control office at Somers Town

(4) No alteration may be made in a district carman's scheduled work without obtaining sanction from the control office at Somers Town

(5) Any odd men arriving at a receiving office may be used for clearing the office, but for no other purpose without first communicating with the control office. The latter will anticipate the arrival of odd men, and endeavor to give instructions so as not to occasion delay

(6) Clerks in charge of call offices will be responsible for calling the attention of the controller to any district carman who fails to call at the office for instructions if he is scheduled to do so

From the foregoing it should be plain what a thorough knowledge the cartage controller has at all times of the movements of every vehicle under his control. It is through this system that an efficient and economical cartage service is maintained.

Before leaving this subject it should be mentioned that, through the information supplied to him, the cartage controller is not only able to operate the vehicles to the best advantage, but also is in a position to cater to the daily or even hourly requirements of the traders. One example will serve to illustrate this point clearly. Suppose the district carman in a certain area has orders to make a collection stop at a certain trader's premises every other day and, for some reason, the trader has a consignment to ship on the day the carman makes no call. The trader simply telephones the controller who, either by communicating with the proper call office or another trader on whom he is scheduled to call next that day, gets into touch with the carman. The result is that the carman is notified of the special call to be made and takes care of it, thereby giving prompt service to the trader at little or no extra cost to the railway. A case like this, without a proper control system, would mean either a special trip for a van or putting the trader off until the next day; and, if the traffic were competitive with another railway, the latter plan might cause the railway not only to lose the consignment in question but also to lose all of that trader's business in the future.

Another important function of the controller's office, from the railway point of view, is that of checking the tonnage carted from every trader. In this way the railway can keep a very close eye on the business of the traders who ship over its lines; and, if the traffic from a trader drops off without any apparent reason, an inspector calls on that trader at once. It may be that the service is unsatisfactory or that the carman has made trouble. In any case the matter is dealt with properly and, consequently, very little traffic is lost if the railway can possibly prevent it. Furthermore, by watching the tonnage carted per carman, it is possible for the railway to obtain between 60 and 75-per cent load-efficiency on all cartage vehicles, which is by far the best record I know of in this class of service. These instances show how necessary a controller plan is to the successful operation of a large cartage organization.

As soon as the district carman finishes his collections, he returns to his home station. When he enters the station his van is weighed and he is given a ticket on which the weight of his van and its load are shown separately. The next step is at the "scrutinizer's" box where the "consignment notes" are gone over and from them the "scrutinizer" knows where to send that particular load, so that the van will be berthed close to the car into which the bulk of the goods must be loaded, and so make the barrower's trip as short as possible. The carman then backs his van into the berth indicated by the "scrutinizer." The berth number is marked on the top sheet of the consignment notes. He turns his weight ticket and consignment notes over to the shed foreman, and this finishes his collection work, provided his consignment notes check with the goods on the van. To explain the nature of a "consignment note," single-entry type is the best. They are handed to the railway company with each consignment tendered for forwarding by rail, and should accompany the goods from the van to the car; immediately the goods are checked and loaded, they are passed to the invoicing office. The carman's next duty is to turn over his delivery sheets and any money he has collected from consignees to the cashier's office and obtain a receipt or clearance for both. Then, after putting his horse away, that day's work is over for him.

Following the van load of collected goods, the third operation is the unloading of the goods from the van and the weighing of the consignments. At each unloading berth, a staff is stationed, usually two but sometimes three gangs. Each gang consists of a checker and "caller-off," or unloader, with two or three barrow men. The van is now ready for unloading, and the checker has been supplied with the consignment notes for the load.

As an example, we will suppose "John Brown, Glasgow, 2 packages," is the first consignment dealt with. The packages are placed on a hand-truck by the unloader and the barrow-man is instructed where to take the goods. He also is given the consignment note covering these goods. In this case the two packages are for Glasgow and the barrow-man has been given the consignment note and instructed to take them to "No. 12 loading-up platform." The distance is not great, as the van has been positioned opposite. On arriving at No. 12 platform, he informs the staff working there that his packages are all for Glasgow, and he is instructed to place them in a car labeled as going to that place. The loading staff take the consignment note from him, pack his two packages in the car and insert the number of the vehicle in which loaded, on the consignment note. The goods are

now in the car, and the fourth and last operation is complete.

Although I have only been able to outline very briefly the methods used, I hope it is a sufficient explanation to present a picture of the essential features of English-railway cartage-practice. A paper could be written on each of the headings I have mentioned, and on many others not referred to in this paper. The subject is one that requires close study and as much light as can be brought to bear upon it, if we would know it thoroughly. It took me a large part of the 15 months I was abroad to learn what I know about it, but I feel that the time spent was justified, for I am convinced that many of the English-railway cartage-methods, especially the principal features of their cartage-control system, can be applied to great advantage in solving our railway cartage-problems if we are willing to learn.

The Field for the Motor Truck

The field for the motor truck lies in a properly coordinated, well organized collection-and-delivery service for the cartage, drayage, trucking, or whatever the term may be, of the miscellaneous-goods traffic of every railway terminal in every city of this Country. I am not mentioning the short-haul traffic now performed by the railways within a 25-mile radius of our cities, and which offers a tremendous field for organized motor haulage. Moreover, that the railways would be glad to let the motor trucks handle this traffic, is not a rash statement to make. Again quoting Vice-President Lee of the Pennsylvania System:[3]

> There is just one more subject upon which I would like to touch, and that is the limits of distance within which the motor truck, instead of acting jointly with the railroad, may be regarded as fitted to take-over merchandise freight service in its entirety. In my opinion, all freight service within city and highly developed suburban areas should be performed entirely by truck, except those special cases involving single pieces of such great weight as to necessitate the use of railroad equipment and roadbed. Otherwise, the railroads ought to be relieved altogether of intra-city business, so that their tracks within the municipal areas may be reserved entirely for the purposes for which they were constructed, namely, the rendering of the strictly terminal service required in connection with the line hauls.
>
> Outside of the strictly cosmopolitan districts, the question of determining the economic limits of truck operation resolves itself into one of determining the point at which the cheaper costs of truck service within terminal zones begin to be overcome by the greater efficiency of the line haul by the railroad. The distance would naturally differ for every center. It may sometime have to be designated, more or less arbitrarily, for every cosmopolitan district, by regulative authority. Possibly a fair average distance might be 25 miles around every large city. Within a circle of some such radius most of the less-than-carload work can be done more efficiently if performed entirely by trucks. Outside of it, the greater efficiency will be obtained by the use of trucks for collection or delivery, and the railroad for the intermediate line haul.

Therefore it should be unnecessary for anyone to need to point out the field for the motor truck in this Country for, in my opinion, the motor truck is on the eve of entering a field of activity that will make the transportation of people and things, from one part of the earth's surface to another, cheaper and easier than today appears to be possible of accomplishment. The opportunity awaits us and, if the transportation men of this Country fail to take advantage of it, we deserve to suffer the consequences. I am convinced of one thing; it is that to solve our transportation problem we must labor unceasingly, give and take, cooperate and grasp every opportunity we can to perfect ourselves. If we all of us, railway men, road-transport men, traders and the public, earnestly and honestly do these things, we are sure to succeed.

Horse Transport

I have a very soft spot in my heart for the horse, provided he is kept in the proper place and that is not where a mechanically propelled vehicle is cheaper and quicker. Anyone lacking even an elementary knowledge of transport who stops to observe the traffic congestion in our large cities can see that the horse vehicle is unsuitable for much of the work it now performs. The experienced observers know that, if loading and unloading were more efficiently handled and less subject to delay, the economic field for horse transport would be reduced beyond the conception of most people. Even as matters stand today, were accurate costs known, it would be found that the motor truck should replace a very large proportion of the horses used in the urban centers of not only this Country but those of other countries as well.

As an instance of what has happened in this matter abroad, according to J. H. Brodie, city engineer, at Liverpool, England, in 1919, along the line of docks, horse-drawn vehicles handled 98.4 per cent of the tonnage and mechanically propelled vehicles handled 1.6 per cent. In March, 1922, horse-drawn vehicles handled 52.4 per cent and the mechanically propelled vehicles 47.6 per cent. I assure you that an Englishman is hard to change; so, you may rest assured this Liverpool change is entirely warranted by the facts and figures. Moreover, the English horses are wonderfully strong, and 12 to 13 tons is a common load for two horses on the Liverpool docks.

The Unit Container

On the subject of the unit container as applied to traffic for interchange between the railway car and the road vehicle, I have discussed this subject at some length with both railway and road-transport men abroad as well as in America. My conclusions are that, without radical departure from present-day practice, it is only for special classes of traffic that the unit container can be used to great advantage.

Fig. 1 shows the Vickers duralumin unit-container of 3-ton capacity. Its unladen weight is only two-fifths that of an oak container of equal capacity. The containers shown in Fig. 1 have proved to be much more economical than any other type I know of. They are constructed of duralumin, a metal that is described at length by R. W. Daniels.[4] The technical editor of *World's Carriers*, London, Hugh Miller,[5] wrote about this container as follows:

> The Vickers duralumin sling-van has not as yet been made of sufficient size for the furniture removing or like business so far as we know. The one we saw, and which we illustrate, was about half the size of the furniture remover's sling-van, and is being used so far experimentally only, but we cannot conceive it as a failure. The actual weight is about two-fifths that of an oak van of equal capacity; that is, assuming the weight of an oak van as 1 ton, the duralumin van would weigh 8 cwt. only, and where the rate is 80

[3] See THE JOURNAL, February 1923, p. 154.
[4] See THE JOURNAL, December, 1922, p. 477.
[5] See *World's Carriers*, (London) Feb. 15, 1921.

shillings, or about $20 per ton for the goods transported, a quite usual rate for the class of goods carried in such vans between London and Liverpool, for instance, there is a direct saving of £2 8s, or approximately $12, without counting the freightage for the returned empty. Besides the advantage gained in the reduction of weight, the Dartford Engineering Co., the container manufacturer, claims a great reduction in the cost of maintenance, though of course, that has yet to be proved. The weather has no effect on duralumin and, with equal treatment, duralumin vans should outlast by a great many years those built of oak or other wood, though that also remains to be proved. The question of strength is, of course, of very great importance. If actually subjected to load-tests, duralumin vans would carry three times the loads of the wooden ones, but the main idea has been to combine lightness, strength and durability, the last two relating to its power to resist impact blows against railway trucks, ship hatchways and docksides. Vickers duralumin has a tensile-strength and hardness equal to good quality mild steel; it is not an easy metal to handle, and considerable experience in its heat-treatment is required. The cost, of course, is high, as that of the metal is also; but, as we have explained above, the

FIG. 1—A 3-TON UNIT CONTAINER THAT IS BUILT OF DURALUMIN AND WEIGHS WHEN UNLOADED, ONLY THREE-FIFTHS AS MUCH AS A WOODEN CONTAINER OF EQUAL WEIGHT

extra cost is soon accounted for by the saving in the cost of transport, and we anticipate that there will be a further compensation in the lower cost of maintenance. In the case of an industrial motor-vehicle body, the weight can be got down nearly three-fifths, thereby giving greater carrying capacity and attendant advantages.

In discussing these containers with Mr. Griffiths, the manager of motor vehicles for Lyons & Co., London, the first firm to use them, he told me that after 1 year's service the maintenance and repair cost was practically nothing, whereas the cost of repairs to their wooden containers was very high.

An English railway executive, the general manager of one system, sums up this whole subject of containers in a clear and concise way in a letter to me that reads as follows:

> You asked me for an expression of opinion on the use of containers for goods traffic. My view is that in the course of time containers will be inevitable, because it is one of the few means of reducing goods terminal-costs. Their use implies that trade customs will have to alter and people will have to purchase in

FIG. 2—TRANSFERRING ONE OF THE "DEMOUNTABLE FLATS" USED BY THE LONDON & SOUTHWESTERN RAILWAY FROM THE MOTOR LORRY TO THE "STAND" LORRY

larger quantities before such devices could be effectively used, and the railway companies might be persuaded to offer lower rates for traffic carried in containers and conveyed at the owner's risk. Apart from the great saving in handling goods which would follow the use of containers, there should be a diminution in pilfering, or thievery, and a considerable saving to senders through not having to provide individual packing. Take, for example, hosiery, boots, cloth and the like. Suitably designed receptacles could be loaded by the senders and sealed. I am afraid that a lot of water will have to flow under the bridge before we see containers in general use, because, as you know, great events move slowly and, due to the present attitude of the public toward the railway companies and carriers generally, transportation agencies probably would be expected to provide all the necessary receptacles at their own cost and pass the benefit on to the traders. As you will appreciate, the cost would be very heavy; because, not only would containers of a suitable size have to be designed sufficiently strong to resist reasonable wear-and-tear and yet be light enough to make them mobile, but the railway vehicles would have to be redesigned in order to get a paying load, and road vehicles similarly would have to be made of such a size as would conveniently accommodate one or more containers. In other words, some measure of standardization would have to be aimed at, and both containers on the one hand and railway and road vehicles on the other would have to be made to fit each other economically.

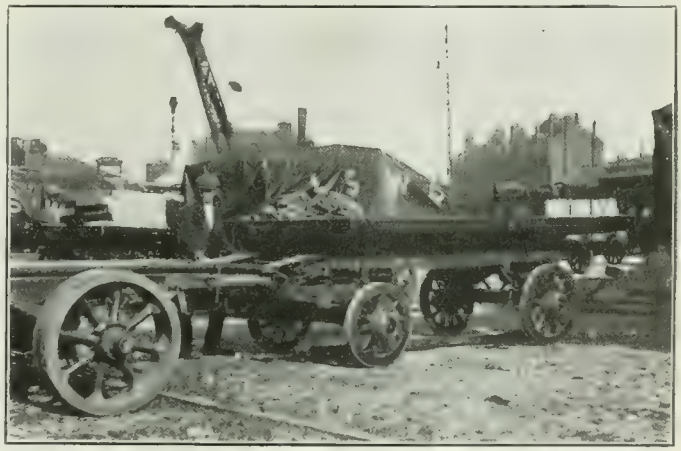

FIG. 3—THE "FLAT" IN POSITION ON THE "STAND" LORRY READY FOR ANOTHER LOAD

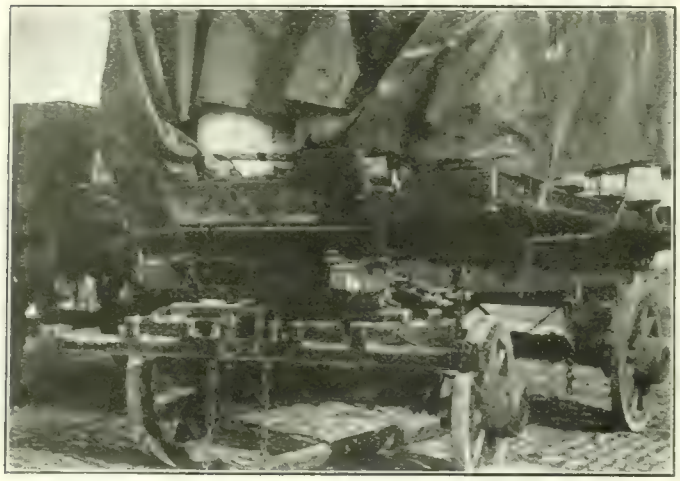

FIG. 4—THE "STAND" LORRY WITH THE LOADED "FLAT" READY FOR TRANSFER TO THE MOTOR LORRY

An analysis of this railway man's statement shows that, before the unit-container system can be used generally in transportation, the traders must be willing to bear their share of the cost of developing it because they will benefit by it far more than the transport interests. Therefore, an earnest cooperation of the give-and-take variety between the traders and the carriers of freight is absolutely essential if the use of unit containers is ever to get beyond the experimental stage, in which it stands today. This whole picture is made up of three major parts: namely, the container, the motor truck and the railway car. To obtain the most efficient freight transportation, each one is dependent on the other.

DEMOUNTABLE "FLATS" OR BODIES

Before going to the subject of tonnage handled, cartage costs, and evidence showing that the English traders prefer their railway collection and delivery methods to ours, I will describe a "demountable-flat" device that is being used with considerable success on some of the English railways. Fig. 2 shows a London & South Western Railway "demountable flat" being transferred from a motor lorry to a "stand" lorry. In Fig. 3, the flat is in position on the stand lorry ready for another load. Fig. 4 shows the stand lorry with a loaded flat ready for transfer to a motor lorry. In Fig. 5, the loaded flat is being locked into place on the motor lorry by the driver. Fig. 6 illustrates the transferring of a loaded flat from a stand lorry to a motor lorry; two men transfer a loaded 4-ton flat with ease.

FIG. 5—THE LOADED "FLAT" BEING LOCKED INTO PLACE ON THE MOTOR LORRY BY THE DRIVER

The London & South Western Railway, through the use of "flats," increased the tonnage moved per day per motor truck almost 40 per cent within 6 months and, although the system is only practicable under certain conditions, the same idea, possibly in a little different form in certain cases, could be used to good advantage in this Country.

CARTAGE COSTS AND TONNAGE HAULED

In 1919, the latest year for which complete figures are available, the annual tonnage of miscellaneous goods carted by the London railway companies was 4,577,100 gross tons. The distance each ton was carted was from 1.78 miles on the Great Eastern Railway to 4.08 miles on the Great Central; the average for all railways in London was 2.46 miles. The average cartage cost per ton in September, 1922, for one of the largest railways in London was approximately $1.80 per ton; at Sheffield,

FIG. 6—TRANSFERRING A LOADED "FLAT" FROM THE "STAND" LORRY TO THE MOTOR LORRY

The Transfer of a Loaded 4-Ton "Flat" Is Easily Accomplished by 2 Men

for the same railway, the figure was approximately $1.25 per ton. So far as I know, we have no reliable figures available that it would be fair to compare to those given above; but let us imagine for illustration that, in New York City, a 5-ton truck at $30 per day can take two loads of 5 tons each from a railway terminal in an 8-hr. day. The cost to the trader then would be $3 per ton. Of course, if the truck handled five loads per day, but with only the same aggregate tonnage, the cost per ton would remain the same. Under ordinary conditions pertaining to this class of traffic, this is a fairly accurate picture of our cartage costs in railway-terminal service in large cities.

UNIFIED CONTROL OF CARTAGE

The best solution of the problem we are discussing probably will be found by organizing either one national system for the whole Country or else one system in each of our large cities. That is the weak spot in the London cartage arrangements, but their transportation men know it, as will be seen from the following statement on the subject by the prominent railway official previously quoted.

> I have given much thought during the last 6 years to the London cartage arrangements. It is my opinion that, if provision has to be made for increased traffic

at a minimum of expense, the only way that this can be accomplished is to get to the source of the difficulty by organizing the receipt and despatch of traffic at the trader's premises properly, and systematically controlling conveyance through the London streets, as an effective organization of this character cannot be established until the railway cartage arrangements are controlled by one authority and an operating policy applied which will be common to all.

Opinions Regarding the English System

The opinions of several of the English trade organizations as to whether their railway collection and delivery service is satisfactory to the trader are quoted herewith. I should first explain that the American system of letting the traders do their own cartage is known in England as the "S to S," meaning station-to-station system; the "C & D" system refers to collection and delivery. Included in the list of associations approached by me regarding the matter are the Federated Associations of Boot and Shoe Manufacturers of Great Britain and Ireland, Papermakers Association of Great Britain and Ireland, National Association of Biscuit Manufacturers of Great Britain, Association of British Chemical Manufacturers, British Food Manufacturers Federation, Silk Association of Great Britain and Ireland, Inc., and the Leicester Chamber of Commerce.

Opinions such as the following, are expressed:

> This Federation prefers the system of delivery to destination to that of carrying "S to S" only.
>
> We do not consider that it would be an advantage to the trading community for the railroad companies to discontinue collecting and delivering goods. It would, in our opinion, not be so satisfactory to the traders as the present system.
>
> The attitude of this association to the questions you raise is that it considers the English system whereby the railway companies have power to collect and deliver merchandise by horse-drawn or mechanically propelled vehicles is greatly to the advantage of the trader.
>
> It would, so far as this country is concerned, be physically impossible for each trader to perform the collection and delivery of his own traffic, especially in the large towns, as it would lead to congestion and consequent delays to the traders' vehicles at the railway stations. Moreover, it would result in the railway companies' not being able to send goods delivered the same day as received at their stations.
>
> Outside of one or two of the larger firms in this industry, there are very few which have their own motors or cartage facilities, and it is largely to the advantage of the trade generally that the cartage should be in the hands of the railways as a convenience to them.
>
> The present system of cartage of goods to and from railway stations by the railway companies is entirely satisfactory. The greatest drawback to cartage by traders is the varying time of arrival of goods-trains, which means the keeping of vehicles especially for the purpose of fetching such goods at practically a moment's notice: whereas, the railway companies deliver promptly immediately on arrival. Moreover, the railway system of collection is better than could be arranged by private firms which, in many cases, would have to make special journeys for the sake of a single article.

In conclusion I ask everyone who can do so to read and ponder what Vice-President T. C. Powell of the Erie Railroad Co. said in closing an address to the Men's Club of East Orange, N. J., in 1922. He said:

> The important thing is the total cost of marketing, and marketing is made up of many items. In some instances and on some commodities the smallest item is that of transportation, but whether the transportation cost is a large or small proportion of the total cost of marketing, it seems to me without question that the greatest economy in transportation can be brought about only by a correlation of the various facilities for transportation. Instead of setting up ruinous competition and expending extravagant sums for disconnected facilities, capital will be conserved, waste will be eliminated and economies will be put into effect that will result in benefit to both producer and the consumer if we will sit down in sober earnest, outline a national policy of transportation and then work to that common end with the same spirit and consistency that in an army actuates "horse, foot and artillery" when struggling to achieve a victory.

IMPROVED STORAGE-BATTERY CONSTRUCTION

THE paper by Clarence W. Hazelett published in the October, 1922, issue of The Journal entitled the Storage Battery as a Mechanical Problem was presented nearly 2 years ago before the Cleveland Section of the Society. In view of the fact that some difficulties were encountered and improvements made in the interim, it may be interesting to report them here.

The original construction involved the use of a wood-fiber separator that entirely filled the space between the plates. This construction did what was claimed for it, but in addition did some unfavorable things, under certain conditions. It was found that, although the excess gas escaped on charging, a certain amount of gas was trapped in the pores of the separator or in the very small space between the plate and the separator. This film of gas increased the internal resistance, causing the cell to heat seriously, particularly near the top of the plates, where the greatest amount of gas was trapped. As heat is the most serious enemy of grids, active material and separators, considerable trouble resulted under the conditions of service where the overcharging was considerable, i.e., where the charging rate was too high or a large amount of driving was done for the use made of the lights and the starter. On the other hand, under normal charging conditions the results have been splendid.

To make a product satisfactory under all conditions, it was found imperative to return to the grooved wood separator. This change was made a year and a half ago, while the use of a much larger number of thinner plates was of course continued. Experience shows that a large number of thin plates is far superior to a smaller number of thick plates, in both performance and life. The continued trend toward thinner plates by other large manufacturers is a result of this fact. It is to be noted that, other things being equal, thin-plate batteries are always more expensive than the thick-plate ones, either in vehicle or starting batteries.

The real practical advantage of the thin plates may be summed up as follows: (*a*) better starting performance, particularly with stiff engines; (*b*) much less tendency to buckle and inability to do damage when buckled; and (*c*) the positive decrease of shedding. The last point has been a surprise to us, but it is a well-known fact that other thin plates very seldom fail through shedding of the material. The failing point in thin-plate batteries is the final disintegration of the grid, normally the longest-lived part of a battery.

The fiber separator is still used as a temporary separator in shipping charged elements. On receiving these elements the service-station removes the fiber separators and replaces them with the grooved cypress separators furnished for that purpose. The advantages of this system in saving time were set forth in the previous article.

What Is Right with the Motor Truck Industry

By Stephen G. Thompson[1] Cleveland Automotive Transportation Meeting Paper

THE author doubts the wisdom of published questions accredited to a prominent editor who asks: "What is wrong with the truck industry?" since this wording blazons an inference that something is wrong and fosters a belief that motor trucks cannot be sold and operated at a profit and the facts marshalled by the author indicate that actual conditions are directly to the contrary. He believes that the broadcasting of a question that indicates the motor-truck industry to be unsound is dangerous as well as untrue, and quotes statistics of production and usage as compared with those of passenger cars to prove his contention.

The history of the motor truck is reviewed briefly and the great changes in conditions of transportation demand are stated as conclusive proof that the motor truck is a permanent asset, that there is nothing fundamentally wrong with the motor-truck industry and that, to the contrary, the motor-truck industry is fundamentally *right*.

IN an interesting article on motor-truck development, written by David Beecroft, he asks: "What is wrong with the truck industry? * * * Why is it that this machine cannot be sold at a profit and operated at a profit?" The position and influence of the publications of which Mr. Beecroft is a director merit recognition, particularly when he projects the serious charges and implications that his questions convey and that, if true, would spell the end of the motor-truck industry. If a thing cannot be sold and operated at a profit, it would soon destroy its own market, for no rational person would invest in machinery that it would not pay to operate, nor would the producer continue to manufacture at a loss. The facts in the case are that the purchasers are continuing to buy, and the makers are continuing to produce motor trucks. The established companies are overwhelmed with orders and the demand exceeds the present rate of supply.

The motor-truck industry is comparatively young, and it is going through the "growing pains" that all industry experiences in its development. Unfortunately, the motor-truck industry is so closely allied to the passenger-car industry that the recent astonishing growth of the latter has overshadowed developments in the former, and we are inclined to judge from the comparative aspects of the two industries as they appear today. This error has led to the general belief that the motor truck is not progressing, and even bankers have asked the same question that Mr. Beecroft put forth in his article: "What is wrong with the motor-truck industry?" When such questions emanate from important sources, we are apt to accept the implications without investigation, and to support our opinions by relating individual cases of failure with which we are familiar. While this is a very natural thing to do, it often leads to gross error. When this error is made by one whose influence is strongly felt the consequences are likely to prove serious.

I am not finding fault with Mr. Beecroft's viewpoint as a whole. Unfortunately, the form in which the article is printed blazons the words, "What is wrong with the motor-truck industry?" and the arrangement emphasizes the belief that motor trucks cannot be sold and operated at a profit. The casual reader is very apt to draw his conclusions from the headlines without digesting the text. Newspapers have capitalized this fact for years. Startling statements and innuendoes have been the life of newspaper circulation. It is the blazoned headline that I am criticising, not the text of the article, which is constructive. I would not for a moment belittle the good work Mr. Beecroft has done toward the development of the automotive industry. However, I cannot but believe that his viewpoint, as indicated by the headline, specified, is based on the current opinion that something is wrong with the motor-truck industry because it did not react as rapidly as did the passenger-car industry after the recent business depression. The reason I am discussing the matter at all is that I believe that the broadcasting of a question which intimates that the motor-truck industry is unsound, is not only dangerous, but is contrary to the facts. In support of this belief, I present the following comparative analysis of the passenger-car and motor-truck industries.

This analysis presents the history of the development of the motor-truck industry and compares that history with the development of the passenger car. Our conclusions, from the facts thus presented, will show that there is nothing wrong with the motor-truck industry; that its progress has been as rapid as has that of the passenger car, and that its product has surpassed the passenger-car product in durability and service. For the purpose of our analysis we will take figures published by the National Automobile Chamber of Commerce. These disclose the following pertinent facts:

Statistical Data

In 1909 the motor-truck industry had grown to the point where the total production for that year was approximately 3250 machines. The following 13 years showed a growth in the industry to a point where there were registered 1,330,000 motor trucks. This 1,330,000 motor trucks, registered in 1922, represents the sum total of the manufacturing effort of the motor-truck industry from its insignificant production of 3250 trucks in 1909 to its production of 240,000 in 1922.

Comparing this record with that of the passenger-car business, in 1899 the passenger-car industry had reached the point of production approximating that which is shown for the motor-truck industry in 1909. The records show this to be 3700 passenger cars. In 1912, 13 years later, the passenger-car registration in the United States was 1,033,000 machines. This 1,033,000 machines registered was the net result of the first 13 years of manufacturing in the passenger-car industry from the time when its production had reached 3700 cars. Compare this with the 1,330,000 machines as a record for the motor-truck industry in the first 13 years following the time when its production had reached 3250 cars, and we

[1] M.S.A.E.—Consulting engineer, White Co., Cleveland.

find that not only is there nothing wrong with the motor-truck industry, but that it outstripped the passenger-car industry by about 30 per cent in its net result in total registration. Today, the difference between the passenger-car industry and the motor-truck industry is merely a difference of 10 years in age, not a difference in the fundamental values of the two products. Certainly, one would not expect as much from a boy 13 years old as from a young man 23 years old.

The astonishing history of the development of the passenger-car since 1913 is now common knowledge. Whether or not the motor-truck industry is destined to repeat that history is a matter of conjecture. It is apparent, however, that the market is more restricted in its gross consumption than the market of the passenger car has been, for the reason that fewer people have a use for motor trucks than for the passenger vehicle.

Motor-Truck Sales and Operation Profits

When Mr. Beecroft asks, "Why is it that the motor truck cannot be sold at a profit?" he loses sight of the growth of the manufacturing institutions of the motor-truck industry and of the financial statements of those motor-truck companies who have directed their attention to the production and sale of the motor truck in its entirety as a transportation unit, rather than to promotion and financial manipulation. Also, when he asks, "Why is it that motor trucks cannot be operated at a profit?" he loses sight of the vast investments made individually and collectively by motor-truck operators. These investments, in many cases running into millions of dollars, stand as a testimonial to the record of economy and reliability of motor trucks in the service of the purchasers. When he says that motor vehicles cannot be operated at a profit, he ignores the growth of motor-truck fleets, in many cases amounting today to several hundred and, in some cases, more than 1000 machines. When he says motor trucks cannot be operated at a profit, he ignores the record of performance of motor trucks in service which have run from 100,000 to 500,000 miles and more and are still rendering efficient and economical service.

"The world counts the hits, not the misses," and the record of development of the motor-truck industry and of motor-truck operation is one of repeated "hits" so far as the industry is concerned. The "misses" have, in a large measure, been on the part of those purchasers whose selection of equipment has been made without due regard to the stability of the organization behind the truck; to the record of performance in service; to the manufacturing, sales and service organization; and to the reputation and responsibility of the manufacturer in the motor-truck field.

Development History

The history of the development of the motor truck is a history of progress. It is a record of transition in methods of transportation. The success of the motor-truck industry stands as a monument to the original perception of the early crusaders in the industry who were farseeing enough to be convinced of the eventual success of the machine as a necessity; plucky enough to venture enormous investments and patient enough to withstand the exasperating trials of development over a long period of time. The human mind is not prone to change from one method to another. This attitude undoubtedly is of benefit in society in preventing the enormous losses that might result from instantaneous or hysterical transition from one practice to another. Unfortunately, it often operates to retard progress unduly, long after changes have been demonstrated to be of advantage to the world at large. We have seen this demonstrated in the application of the telephone, telegraph, typewriter, adding machine, electric light, trolley car and many other commercial utilities.

The motor truck has encountered and conquered this eternal barrier, and, to its credit, it can be said that, in conquering, the battle was won solely because of the economic value of motor-truck transportation. Unlike the passenger car, the motor truck has no popular appeal to fancy. It is not influenced by personal vanity or pride. There is no "living up to the neighbors." The motor truck is an essential thing in the world of business today; it is an essential because it is in keeping with our industrial progress. Motor-truck operation marks a forward step in transportation. It is a natural consequence of the development and expansion of railroads.

The Changing Aspect of Transportation.

Railroad development permitted the concentration of manufacturing industries on a large scale at points convenient to their raw materials or for the distribution of finished products. It opened vast uninhabited regions to immigration and prosperity. By bringing the products of distant regions to the toiling millions of the cities, the railroads have made it possible for cities to increase in population and prosperity, and the entire civilized race has been blessed by the greater economic efficiency thereby obtained. This centralization of population in towns and cities created problems of transportation which seriously threatened further development of the communities. The frontiers of the cities pushed farther and farther into the surrounding country. Distances within the populated areas became greater. There was an increasing demand for food in larger quantities. This demand naturally stimulated the development of food-producing areas adjacent to these consuming centers. As the cities grew, these producing areas not only moved farther and farther away, but they also expanded to meet the demand for an increased production caused by the increased population. This development, like the proverbial flea on the flea, proceeds ad infinitum. Consequently, gardeners and dairy farmers who, a few years ago, were faced with a short haul to the nearby market, now find the horse-drawn vehicle of other days entirely inadequate to cover the increased distance to the cities where they dispose of their products. In the same way, the delivery areas of the city merchant and of manufacturing industry have all expanded with the changing conditions of our political economy.

The changes wrought by the centralization of industry have resulted in a disturbing disproportion of population in the rural and urban communities. In 1880, the population in the rural sections was 70 per cent of the total. Today the conditions are reversed, and 70 per cent of the people now live in cities; they produce manufactured products and depend on the other 30 per cent for their food supply. In the transition, the complexity and aspect of transportation is constantly changing. What was adequate transportation a few years ago is entirely inadequate today.

Increasing problems of traffic congestion have claimed the attention of railroad operators and engineers for the past 10 years and, at times, congestion has become so acute as greatly to impede freight-traffic movement. An entirely new phase in transportation has developed. The proposition is constantly before us. We see it on every hand. Compare the conditions of living in the city with those of the small rural community, and the facts in the

ease are very apparent. The problems are insignificant in the small towns, but the complexity increases in the city and with the growth in the population. Nationally, the interchange of commodities and the interrelation and common interest existing between the communities, the states and the nation, constantly multiply the complexity of transportation. The development of the telephone, the telegraph, the postal service, the passenger automobile and the railroad have all contributed to ease of communication and dispelled isolation. This has created a demand for rapid and economic distribution of freight and passengers beyond the ability of the railroad and horse-drawn wagon to supply.

Motor Trucks Are Permanent Assets

The motor truck has established itself in this field; it is the connecting link between the wholesaler and the retailer. Today, transportation is divided between the wholesale user, and what might be termed the retail user. Bulk and low-rate freight is transported from the producing to the distributing centers, where it is reshipped to the retail consumers. These retailers market miscellaneous products at home and in the nearby cities, either directly to the consumer or through wholesalers, packers or jobbers. For the former class of service the railroads offer adequate transportation facilities, especially for the longer distances between the point of production and the market. For the latter, this form of transportation is available in but a limited degree, for it is obvious that the ramifications of the railroads cannot be expanded to the form of a series of spider's webs radiating from industrial centers and reaching all communities.

So, the motor truck has come to be a necessity; first, because of its value as an economical and efficient means of transportation; second, because the increasing complexity of our modern civilization has developed a demand for a new and better expansion in transportation that can adapt itself to changing conditions and that is, in large measure, unrestricted in its direction of operation. This demand not only applies to the freight-carrying vehicle, but to the motorbus as well. When properly correlated with steam and electric-railway systems, motor-vehicle operation insures the public convenient and economical transportation. It destroys nothing that progress has constructed, but rather increases the efficiency of those institutions.

Today, the motor truck constitutes our primary transportation system, delivering direct to the consumer or to the steam and electric railways for long-distance hauling. Its worth lies in *the value of the service rendered*, and it is in recognition of this value that Mr. Beecroft reiterates the conviction that the commercial vehicle is ushering in a new era of motor transportation. It is in recognition of this value that the fleet owner purchases motor trucks as a new factor in transportation capable of expanding his business zone; improving the character of his distribution and influencing the volume of his business by creating a constantly widening market.

The "Right" of the Motor Truck

This is the story of the history of the motor-truck industry. It is the story of the reason for the development of the motor-truck industry, and it is the story of the value of motor-truck operation. This story is the answer to the question, "What is wrong with the motor-truck industry?" The story tells what is *right* with the motor-truck industry. The "right" of the motor-truck industry is that it is based on the application of machinery methods to highway transportation. The application of machinery methods has resulted in mass production and improvement in all industry. It has created economy in cost. As a machinery-using nation, the United States has outstripped the world. If we make our goods by machinery, transmit our messages by machinery, write our letters by machinery, and do our arithmetic by machinery, and if, as an industrial nation, we have progressed through the use of machinery, it is logical that our highway transportation should be by machinery. Therefore, the motor-truck industry is fundamentally right.

I feel the industry owes a debt of gratitude to Mr. Beecroft. He has asked pertinent questions that have been uppermost in the minds of many. In this he has performed a valuable service; for, through his action, we are given this opportunity to tell the real story of the development and stability of the motor-truck industry.

TESTING ROAD PERFORMANCE

THE driving characteristics of popular cars, chiefly British, but including also some well-known American makes, are being discussed in a series of articles appearing in *Autocar*, London. The observations necessary for comparing the performance of the different cars are made during a test run over a standard route.

One of the standard test-routes is an 80-mile loop starting and ending in London and extending to the southwest for a distance of over 30 miles. It will be noticed that the first and last stretches entail traffic work. Incidentally, Putney Hill, just outside of London, provides an interesting comparative test owing to the fact that it must be taken from a crawl because of traffic conditions. Twenty miles out of London, the route includes the Brooklands race-track, where a special schedule furnishes most of the numerical data for the performance tests. Thus, the weight of the car and passengers, the time for a mile at full-open-throttle, the acceleration figures, the hill-climbing power and the brake performance are all determined at Brooklands. Before leaving Brooklands, an exact ½ gal. of gasoline is measured out for the drive from Brooklands to Newlands Corner. This stretch of road constitutes a fair sample of main-road, by-road and uphill work and is covered at a normal average speed with no coasting and no variation of carbureter setting, so that twice the speedometer reading, when the ½ gal. of gasoline has been consumed, should give a fair figure for the average miles per gallon.

The rest of the route offers opportunities for testing the suspension system, the steering properties, the engine vibration, the road-holding qualities and the hill-climbing characteristics of the car. In fact, with the exception of durability and upkeep, practically all features that affect the relative merits of a car may be judged on the standard test-route by a competent observer who has handled 100 or more cars over the same route.

This represents an ambitious though rather non-technical attempt on the part of the above-named journal to secure some reasonably reliable information and is a distinct advance over most attempts of this kind. An attempt is made to get real measurements of weight, maximum speed-acceleration, reserve power on hills and brake performance, in addition to the observation of general performance of the cars on standard test-routes that have been carefully selected to give average road conditions.

Discussion of Papers at the Annual Meeting

THE discussion of the papers presented at the recent Annual Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum of effort.

In addition to the discussion printed in the April issue of THE JOURNAL and that given below the discussions of the two papers presented at the Engine Cooling Session, Aircraft-Engine Practice as Applied to Air-Cooled Passenger-Car Engines, by S. D. Heron, and Cooling Capacity of Automobile Radiators, by E. H. Lockwood, will, it is expected, be published in the June issue of THE JOURNAL.

TESTING LEATHER SUBSTITUTES AND TOP MATERIALS

BY J. B. DAVIS

ALTHOUGH waterproof protective material has been in use for many centuries, particularly in the Far East, its manufacture in this Country was not begun until about 1850, and not until the arrival of the motor car did the demand for so-called leather-cloth cause its production to take a jump. This demand has increased until in 1922 the record-breaking quantity of 50,000,000 sq. yd. was consumed. The growing popularity of closed bodies has produced a corresponding call for leather-cloth and the importance of classifying and of embodying standard tests in the specifications for it is receiving close attention.

With the view to assisting in the establishment of uniform tests for the various qualities that are desirable in high-grade leather-cloth, the tests in use by one of the largest manufacturers are described, and suggested specifications for top material, upholstery and special body leather are given. Particular requirements will determine the desirability of muslin, drill, twill, sateen, moleskin or duck, and the suitability of each is judged by the weave, construction, thread-count, weight and the like. Among the qualities that can be determined by tests, directions for which are given, are resistance to wear; tensile strength; bonding-strength; resistance to stretch and puncture; thickness; toughness and adhesion of coating; resistance to water, shrinkage, fire and heat; cleansability and resistance to gasoline and the effect of aging. [Printed in the March, 1923, issue of THE JOURNAL.]

THE DISCUSSION

G. W. KERR:—When I was endeavoring to select the strongest material, the statement was made to me by a salesman that all fabrics having the same structure, weight and thread-count have the same tensile-strength. A manufacturer said that this was not true. What have your tests shown in that direction?

J. B. DAVIS:—The original fabric has a certain tensile-strength depending upon its construction and weight. The tensile-strength is increased when certain strong coatings that intermingle with the fibers of the yarn and help to hold them together are applied to the fabric. Coated materials have a higher tensile-strength than uncoated materials, and some manufacturers bond two fabrics together. The bonding process gives, without excessive weight, the advantages of the tensile-strengths of both fabrics plus that of the bonding cement.

MR. KERR:—Is there not a great difference in the strength of the yarns from which the stuff is woven, so that there is a difference in the tensile-strength of materials otherwise the same; that is, having the same structure, weight and thread-count?

MR. DAVIS:—Generally speaking, that is true. There is the length of staple to be considered, the amount of twist and all the things that particularly concern the fabric manufacturer. It is not possible, just by taking the weight and making the thread-count, to compare the tensile-strength of two materials.

H. C. MOUGEY:—My understanding of these tests is that they were made almost entirely on new material. In the curves you show that some material, when new, may start out with a wonderfully good test, yet in a short time the order may be entirely reversed. Is there any way to test new material to find out how it will stand up later?

MR. DAVIS:—The mercury-arc light reproduces, as nearly as possible, the actnic rays of sunlight. By arranging the equipment to combine the action of water, wind and sun in a cabinet, you can ascertain within a comparatively few days how the material will stand up as compared with the old method that required from 6 months to 1 year.

MR. MOUGEY:—These tests were made on new material and you saw later how they compared on the exposure?

MR. DAVIS:—That is correct.

C. M. MANLY:—This paper parallels and goes beyond, to a considerable extent, the tests that we made on airplane cloth during the war, on both the coated and the uncoated fabric, especially in developing the ultra-violet tests and in the manner of carrying them out. Some of the rubbing tests have been extended very much over the crude ones we had to make. It seems to me that these

tests should be of great interest to the automotive engineer in drawing up specifications and in knowing exactly what materials he is getting, so that he can stand back of the product in the same way that he stands back of the other parts of the car through having drawn up proper specifications for them.

We had considerable experience in determining the strength of airplane material by thread-count. Of course, you can get any kind of results you desire, for they depend entirely on the quality of the cotton, or linen, or whatever it may be, out of which the yarn is made. All the airplane cotton cloth that finally was used was made from long-staple cotton; there was a great difference between the strength of that cloth and of the cloth made from short-staple cotton. The twisting and the mercerizing of it and the different chemical treatments it went through differed greatly in their effects. If you wish to go into the effect of the number of twists, you will find that the shortest route is to subject the material to the tests rather than to go into the intricate matter of the weave and the method of the chemical-processing of the cotton through the mills. We found that we could tell quickly whether the cloth was suitable for airplane covering, if we were given samples of the cloth, but at the beginning it was hard to get information from the cloth manufacturers as to the processes through which they put the cloth. There seemed to be considerable information on that subject that they did not care to disclose.

CHEAPER CLOSED-BODY CONSTRUCTION

BY GEORGE J. MERCER

THE author quotes statistics relating to the proportion of closed to open bodies and outlines the changes that have taken place in body construction in recent years. He sketches the advances that have been made and states that the question to be answered now relates to what all this improvement in manufacturing methods has accomplished toward reducing the price of a closed-car body to the consumer. He compares the percentage of public benefit in 1922 with that of 1914, excluding the period of inflated prices immediately following the war, and states that it is 10 to 15 per cent, but says also that this is an unfair comparison because of the excessive increases in the cost of labor, lumber, sheet steel and trimming cloth.

An unconventional type of body, covered entirely with fabric over a foundation of wire-mesh and buckram fastened to the conventional wood-framing, is illustrated and described in detail, together with a statement of its advantages. [Printed in the February, 1923, issue of THE JOURNAL.]

THE DISCUSSION

E. W. M BAILEY:—This construction possesses some very attractive features. How does the forming of the wire backing, the wire support for the fabric, lend itself to wide change of shape, full-sweeps and the like?

GEORGE J. MERCER:—The body-framing is conventional. The wire is put on and a thin layer of wadding is put between the wire and the buckram, which is three-ply, a scant ⅛ in. thick; after being fastened on, the whole is covered with shellac. That is the only foundation for the body panel that we use. We were surprised to see the stiffness and rigidity that we got from making the body in that manner. The forming of the wire on this body was done entirely by hand. When starting the work, the mechanic told me that he would do the upper round-back corner first, because he thought that was the most difficult part. It was formed so easily, however, that he was surprised. He had no trouble at all. The doors and other parts that are nearly flat take their shapes very easily. The wire gave very little trouble. The buckram was a little more difficult to handle. On the upper round-back corner, we cut the buckram and shaped it as we should shape the cover of a baseball, but we believe that it would be better to soften it, put it over a form, let it dry and then put it on, because the edges that had been cut came through. We had some trouble and had to shave the edges off and pad them a little.

MR. BAILEY:—As I understand it, you wrap this wire round and shape it over the form?

MR. MERCER:—No, we formed the wire first in the same way that a metal panel is formed. We anticipated that we might have to put it under the hammer, but we found that we could shape it by hand by bending it over the shape that we required. We found that we could get the required shape and then see whether it was right. We could flatten it or draw it out after it had been applied.

MR. BAILEY:—In mass production, would you require a form?

MR. MERCER:—Yes.

CHAIRMAN GEORGE GODDARD:—Did you find that you were obliged to make the wood framing somewhat stronger at the joints than would have been necessary with metal panels that really function like gussets to the frame structure?

MR. MERCER:—We had that in consideration at the time, and finally decided that it would make no difference. The door is an illustration. It is conventional. It would be the same as and no heavier than if we applied metal panels to it. We really do not anticipate trouble. It might happen that in some designs one portion would be weak on account of not having bracing, but we do not anticipate such a contingency in the construction that we already have fabricated.

The metal-panel body, in a sense, is rather peculiar. We get strength from the panels and, at the same time, the doorway cuts-out a large part of that strength; so, the body really is not so strong as it apparently would be on account of the steel panels being there.

CHAIRMAN GODDARD:—That brings up the question of the uniform flexibility of the body of a motor car. Engineers who have had experience in chassis construction know that we have gone to three-point engine-support in various forms to obtain flexibility of the chassis and to avoid cramping the crankshaft bearings and the power-plant in general. That means, naturally, that the frame will weave and become distorted temporarily. Very few body engineers have grasped entirely the meaning of that distortion and its effect on the body which is required to absorb it. In an open body, the door-openings practically cut the body into halves, and the sudden reduction in rigidity or, rather, the increase in flexibility, is localized at the sill section beneath the doors. It should naturally, then, be the object of the designer to design a body to be as uniformly flexible as possible; otherwise, he will localize this distortion, which is transmitted to the body, causing the opening of seams and joints between the moldings and the panels and undue wear on the lock-bolts, strikers and hinge-pins. This

particular body-construction strikes me as making the body even more uniformly flexible, and as possibly having some advantages in that direction.

MR. MERCER:—It is my idea that no points will be unequally strong. With the fabric construction and the wire and the buckram, the body is more uniformly strong than it would be with any form of construction now used. There are possibilities in the direction of its being the one perfect body.

CHAIRMAN GODDARD:—The one-day schedule for enameling bodies is really much less than one day. It is 3½ hr. for three coats when the conveyor system is used.

MR. MERCER:—I knew it was a little less. I understood it was 7 hr. for the trimming and the enameling.

CHAIRMAN GODDARD:—Approximately 6¾ hr. from the unfinished steel body to the finished car, but the body while going over the enameling conveyor really undergoes four operations of enameling. For protection against rust, the enamel is sprayed on the inside and the under surfaces; then the three coats are applied successively to the body which, after each coat, passes through an electric oven having a temperature that varies from 450 to 600 deg. fahr., at a rate of speed through the oven that requires from 20 to over 40 min. per operation.

G. W. KERR:—Is that for open or for closed bodies?

CHAIRMAN GODDARD:—It is for open bodies. We are now in our first year of production of the closed body. The reason we use the fabric upper quarter at present is that we took advantage of the fad of the day, the fabric-backed body; and, while it is still in vogue, we shall find out how to enamel that upper back panel successfully without turning the body upside down.

We believe thoroughly in the all-steel body; some day we shall have it. The public is well satisfied with the fabric-backed, all-steel body, which is also quieter. We have fewer sound-proofing experiments to make and the time-element has forced us to use that construction. We have used the body for more than 8 years, and some 800,000 of them are in use. I have seen a body that was enameled in 1914 and has been taken good care of, polished and kept clean, which would take more than ordinary observation to note that it was not new. The enamel does not deteriorate but, owing to atmospheric and temperature conditions, merely collects a residue of bluish scum, as you might call it, a film that is removed readily with the proper kind of polish.

The steel body is in its infancy. I mean, not that every manufacturer eventually will make a steel body, because he will not find enough wood to make use of, but it is merely necessary to have a production of sufficient quantity over which to spread the die and equipment cost. Steel construction, enameled, in the end is cheaper than wood; and, when you consider that a body can be pressed out of the sheet, electrically welded, assembled and enameled in somewhat over one day of actual time, this is very different from the 106 days that it takes us to put through a sedan body from the lumber pile to the finished car. That, however, includes 18 or 19 days of painting operations.

L. C. HILL:—Will wrinkles appear in this material as it is exposed to dampness, rain, sunlight and temperature changes?

MR. MERCER:—I think that question can be answered by looking at the average high-grade fabric roof. A wrinkle very seldom develops in a roof, even after it has been out two or three years. The fabric is put on and is stretched; that is, hot water is applied to the inside, or the cotton part of the goods, then it is put on, drawn and pulled tight; it will shrink out. The effect is much the same as stretching paper on a drawing board.

Fabric that is made to imitate leather has one advantage over leather itself. Leather will sag in time and become stiff and hard. We anticipate, and it has been actually proved by 2 years of hard service, that this fabric will not show a deterioration in that time that would indicate that the goods were used up, or that the car was out of date, or did not look well; it still is in a state in which it is serviceable and will be presentable.

A MEMBER:—Your remark on the uniform flexibility required in body-construction brings up the difference between the requirements of an automobile body and those of a motor-coach. We built the motor-coaches that run on Fifth Avenue, New York City. A material of this sort, although it may serve a purpose in the passenger automobile, would not serve in larger construction such as that of the motor-coach, because we have found that steel panels and similar rigid paneling perform a definite function in the motor-coach. In an automobile body the supports are so close together, so closely interspaced, that the question of the strength of the covering does not arise, but in the motor-coach the question of the construction and the value of the covering is vital, because the steel panels, as a covering for the coach, perform a very necessary function in stiffening the frame and withstanding the stresses against the weaving of the coach and of the chassis.

The structural members, the timber members, are spaced more widely, and that fact makes a rigid covering more necessary. If the rigid covering were done away with, so far as the motor-coach is concerned, it would be necessary to increase the timber sections and to strengthen other parts, and that would tend to make the body more bulky. There is a decided difference between the problem of automobile design and that of motor-coach design.

CHAIRMAN GODDARD:—Inasmuch as reference has been made to my remark, I will qualify it, to refer to passenger-car bodies. The motor-coach type of body is assuming greater importance and very many more such bodies will be built, but I think the remarks just made refer to a coach that runs on solid tires on a smooth asphalt pavement. If that coach had pneumatic tires and were used in interurban service at speeds of 25 m.p.h. and greater, I think my remarks regarding the passenger-car body would apply.

A MEMBER:—Certainly. Greater flexibility would be required at higher speed.

P. W. STEINBECK:—Concerning the turn-under and side-sweeps, would there be bulging between the moldings, or should we be able to get a true line on the side-sweeps and turn-under?

MR. MERCER:—There is no bulging between the moldings that is noticeable. The screws are placed about 2½ in. apart. We have no trouble of the kind you mention. The goods are fastened under the molding; they are nailed or tacked under the molding before the latter is applied, so that the goods are smooth. Then we place the molding in such a way that there is no chance for bulging. Do you mean that the molding would sink in?

MR. STEINBECK:—Yes. If you had a true side-sweep and wanted to eliminate as many moldings as possible, how would the side-sweep be affected, looking at it from end to end? Would there be a true torpedo-shaped line?

MR. MERCER:—We have considerable side-sweep on the body that I have mentioned. The side-sweep is more than the average. There is a large "round" at the back corner and the back also has a considerable "round," more than is usually the case. We have experienced no

difficulty at all. The goods, as I have explained before, are stretched tight and the foundation underneath is firm. It is not a soft, flexible surface, but is firm. For that reason we do not push into it.

MR. STEINBECK:—If you pull the fabric tight, it will draw to a straight line.

MR. MERCER:—It is similar to a built-up coach-roof. We applied the cloth over a solid foundation, as we do with a roof. Over that we put a wood-fiber or some other form of stiff panel; we pull the fabric over that and have no difficulty. It is a very old practice.

CHAIRMAN GODDARD:—You do not apply a layer of wadding under the entire surface?

MR. MERCER:—The surface is made full; the fullness is built-up before the goods are put on.

A MEMBER:—Inasmuch as this panel is so flexible, would it not be necessary to have a more rigid frame? After a body has run for about a year, the old-style panel acts as a gusset or stiffener. Would not the panel loosen and not reinforce the frame, in the same way as that of the old-style metal or wood panel?

MR. MERCER:—Do you mean that the frame would come apart where it is joined?

A MEMBER:—Yes.

MR. MERCER:—We are now demonstrating this. Anything that is a radical change has to be put on the road and tried out; that is the only way to prove it. We might theorize for the rest of our lifetimes and really get no satisfaction, for we do not prove it to any other person. For this reason, a body will be put on the road the first week of February and tried out over hard roads and through bad weather during the spring months to show just what will be necessary in the way of reinforcement. We hope that by fall or before, the test will be concluded. In the spring, from February on, a very severe test can be given a car that will amount to a year's ordinary driving. So we are planning to do that.

A MEMBER:—How about patching? Is that performed as easily as on a wood or metal panel?

MR. MERCER:—Yes.

A MEMBER:—On some bodies, we simply take out a panel and put another in.

MR. MERCER:—The mass or quantity production of today is tending toward bodies made in sections that are complete and can be assembled and replaced. A number of the new makes of cars have bodies made in that way. If that feature were carried out, it simply would be a case not of patching but of replacing the section that had been destroyed or damaged. That would be much easier than repairing it. We provide for repairs by replacements that are made easily.

A MEMBER:—How would it act on a side-chain bus, say a 35 to 40-passenger bus? Would it act like a metal panel on the bottom?

MR. MERCER:—I cannot see that it would make any difference. It will stand up and will keep out water, snow, wind and cold. That is practically all that a panel is supposed to do. For any contingency except a collision, it would be equally adequate. It is in use now for tops and roofs and nothing is thought of it. Formerly, we had solid-panel roofs, but they have all been replaced by the soft roof. It is only a logical step to continue with the rest of the body.

A MEMBER:—The side of a bus works differently from the roof.

MR. MERCER:—The excessive distortion of the framing in a bus would have to be taken care of by additional braces.

MR. BAILEY:—It seems to me that the most attractive feature of this construction is its elasticity rather than its lack of it. This body certainly would be elastic. When I study the elasticity of a closed body, I always get lost. I cannot see why any closed body with stiff panels ever can stand up; I do not see why it does not go to pieces. But in designing, we assume, of course, that the sill of the car should be stiff enough so that there would be no longitudinal undulation, but the two sides of the two sills cannot remain in the same plane; therefore, the body must twist and every closed body must twist. I assume that the only reason it stands up at all is that it twists at the door and that part of the body. Instead of making the frame of this body heavier, therefore, on account of the fabric panel, my idea is that it should be lighter; the joints should be heavy but the body should be lightened elsewhere.

By the use of fabric, we do not gain much in time, if anything, over enameling. We have the trimmer's time to put against that of the enameler; so, there is not much gain there. With regard to the stretching of the fabric, the roof is in a horizontal plane and the fabric on the side panels is stretched cornerwise. I can see that this might cause trouble. Another objection, a thing that might prevent its general adoption, is on the æsthetic side. Mention was made of the beauty and the style that were given to the landau by the long-grained leather in the upper panels. The same thing is being done in bodies today by building the upper panels that way; but the upper panel in a landau, or in any similar body, presupposes that it is to be folded up into a compact space; it was a superstructure on a paneled body that had rigidity and form. If we carry the leather effect into the lower panels we are violating the æsthetic idea.

MR. KERR:—I have made experiments on the twisting of closed bodies and have demonstrated that sound closed bodies can be twisted to a limited extent. I have mounted closed bodies on a limber chassis, with a three-point support, and have jacked up one wheel until I have twisted the chassis 1½ in. lengthwise; the body showed the distortion but withstood the experiment.

In service, of course, they could not withstand a condition like that very long. Chassis engineers will realize sooner or later that the ideal should be the unbendable and untwistable frame. At the Salon shows last year and this year a chassis was exhibited that had a tubular cross-member of very large diameter, designed to prevent the twisting of the frame, and a frame of very deep and very wide section, designed to prevent bending. This year there was a frame, perfectly vertical, that had cross-members in diagonal form in the center of the chassis, an X through which the drive-tube passed. I recognized its object because, 6 or 7 years ago, I saw the experiment tried successfully of making an untwistable frame by placing the cross-members in a diagonal direction, crossing and forming an X, the idea being that if two lead pencils were laid, one across the other, and one were raised, the other would rise an equal amount so that the twisting strains would compensate.

I believe Mr. Mercer's construction would offer a flexibility in a closed body far greater than is possible with a paneled body, but it often happens, even with the stiffest bodies that, if the strain is too great, the glass will break. Glass breaks frequently because of a sudden twist. In the old carriage days, the frame of a coach, until it had been paneled, could easily be twisted; once paneled, it was absolutely immovable; it could not be twisted, and did not need to be, because the springs of the carriage were competent to, and did, take all the twist.

I believe that, in this body of Mr. Mercer's construction, it would be necessary to have very sound and well-made joints; otherwise, they would loosen under the twisting strain. But I think the body would be durable if the joints were good, and that, in most cases, the additional elasticity would be an advantage rather than a disadvantage.

I think a fabric top sags, not because it stretches, but because it shrinks. Leather tops on carriages always shrink. They often shrink until they pull away from the nails. As I understand it, the sagging of a fabric top comes from the fabric's shrinking crosswise, which pulls down the material so that it shows a bony appearance; it is not from swelling but from shrinking.

The substituting of a soft roof for the solid roof has, generally speaking, proved very satisfactory in the deadening of sound and in durability. In the old days, coach-building in England was done with leather as an outside covering for the wood panels. A green hide from which the hair had been removed was stretched over the roof and the side quarters and down over the back. It was nailed down, the edges were covered with molding, and then it was painted, roughstuffed, varnished and finished as if it were wood, but it obviated the danger of having the panels cracking and splitting.

ALVIN HUNSICKER:—I am partly guilty of the fabric that you have been talking about. I have about my neck a collar constructed so that the "stretch" has been taken care of. It is not a fabric; it is two fabrics, each constructed in a different way and the two are put together with waterproof cement. The stretch, the strain, the sagging points that you have mentioned, do not exist in this fabric. When we talk about stretching and sagging, the average single fabric is meant, but this is a double fabric; therefore, all the strain and twist and sag have been taken care of. It has been built to withstand the strains that it is expected to withstand. The soft top is used to get away from the rumble. There must be some rumble left in the frame. The flexibility of this frame certainly should be in its favor, no matter what you put on the outside. The sudden shocks and the twisting that an automobile gets are very bad when there is too much rigidity. We believe, apart from the fabric question, that a light flexible automobile frame has great possibilities.

CHAIRMAN GODDARD:—It is apparent that frames have been made more rigid, much stiffer, than they were in the early days. It is also a fact that springs carry a lighter load per inch; they are of greater flexibility. There should be no springiness in the frame. If there is, the spring in the frame will get out of step with the flexibility of the chassis spring, and the result will be unpleasant. The frame must be stiff; the springs must be flexible, as flexible as possible; in fact, many manufacturers are making the flexibility of the springs such that they are correct for three-quarters of the full passenger-load. In a five-passenger body, the springs are made to ride over roads of average condition with from 70 to 80 per cent of the load; with a five-passenger load, the frame will hit the bumpers on an extreme bump. That is done so that the man who rides alone or with one companion may have a good ride. The average number of passengers carried by motor cars, as checked by E. S. Jordan on street corners over a period of 6 months, was found to be 1.6 passengers per car. So, the chassis engineer who designs a car to carry three-quarters of the load without bumping the axles or bumpers is working safely in the right direction. A frame can be made stiff and still not be heavy or appreciably stronger than a similar section of less vertical height. Rigidity is what is required.

MR. HILL:—The National Automobile Chamber of Commerce canvass that has just been made, showing that 60 per cent of automobile owners want closed bodies and 40 per cent want open bodies at this particular time, ought to lead body engineers to concentrate their efforts on further decreases in the cost of closed bodies.

CHAIRMAN GODDARD:—In a fabric construction, such as that of the old landaulet and landau, we always applied the lead-filled moldings very carefully. Some of them were nickel-plated; others called for black enamel; in many cases, it was necessary to touch up or finish the molding after the fabric had been applied. That is not a production method. The moldings can be put through a low-baked enamel, not a high-baked enamel process. My experience has been that the best molding is filled with half-and-half solder, not lead. The melting-point of half-and-half solder is below the temperatures used with high-baked enamel.

MR. MERCER:—When fabric was used to cover the upper rear back and side quarters of the cheaper closed bodies that were put into the show a year or two years ago, the very imperfect method of fastening it at the moldings was rather disappointing to me. The lead-filled molding presents such difficulties that I think it is not possible to consider it in production. It would be difficult to get workmen who are capable of putting it on properly. Fabric-backed or soft moldings, so-called from the manner of the finish that is used for the interior trimming, never look well because they are not clearly defined. On the sample body, we used an ordinary oval 3/16 x ¾-in. aluminum molding, and put screws through it in a manner similar to that of the Rothschild construction. I do not mean to give that as an illustration; it was very expensive.

A body made by Budd and exhibited at the automobile show typifies the very cleanest form of construction that is possible in applying fabric panels. It is an all-steel body with the panel as an insert. I believe that manufacturers today are arriving rapidly at the point of making bodies in sections and of applying the different parts to the body. This method has great possibilities and many angles that will help to cheapen construction.

Budd's opening is like that of a window frame; the panel is an insert and a piping is applied that is only about ¼ in. in diameter; it closes the opening, makes a neat appearance and can be made by an average workman without too great cost.

The lead-filled molding is too expensive. When I first became interested in the fabric-built body 18 months ago, I found that the expense of making it was greater than that of a steel body. A steel body can be made cheaper than a fabric body unless we can get a better method of applying the fabric and of finishing it where the molding is attached. I think the best plan is to apply a separate panel and to put it on with piping made by bringing the fabric over a reed. The piping is ¼ in. in diameter and is fastened to the panel before it is inserted. The panel is pushed into and covers the opening. It makes a nice finish.

MR. BAILEY:—I have made a large amount of molding to take the place of the lead-filled type, and have used it with fair success on a series of bodies. We used half-oval drawn steel with spot-welded stubby-headed nails on the flat side. We could do it rapidly and without trouble. Spot-welding can be done by anyone. As the molding was of steel, we could use high-baked enamel. I believe I was a pioneer in enameling. We did a great

quantity of it and could dent the steel without spoiling the enamel. I have tried that with this molding very successfully.

MR. KERR:—Mr. Hunsicker spoke about the fabric eliminating all the drumming noise. It would eliminate all the drumming noise that comes from the roof, but the roof is not the source of all the drumming noise in a closed body. I have built closed bodies with aluminum roofs that had no drumming noise, and I have heard plenty of drumming noise in a body that had a soft roof. In a car that had what our English friends call "booming," I put my hands on the glass on each side and stopped the booming. In that case, the noise was caused entirely by the synchronizing of the vibration in the glass with that in the chassis.

MR. HILL:—An apparent rumble in the roof of one series of closed cars was stopped by adding 3 in. to the tail-pipe of the muffler.

CHAIRMAN GODDARD:—The roof picks up vibrations, one class of which is caused by the pulsating of the exhaust. Even in multiple-cylinder engines, lengthening the muffler tail-pipe or increasing its size steps the vibration up to a higher mile-per-hour speed so that the vibration, although still there, is not noticeable because the car is not driven often at the higher speed. In the early days, we eliminated objection to the noise by stepping it up to 30 to 35 m.p.h. At that time, closed bodies were not driven frequently at that speed.

The other is a mechanical vibration, in a four or eight-cylinder engine; the six, not being so bad as either of the others, must, however, be stopped by sound-proofing. Pullman cars, as everyone knows, are very quiet. They practically are all-steel cars. The roof is of steel and, according to the chief engineer, the company does not use, and has not used, wood-fiber panels on the inside, for several years. Steel panels and a means of sound-proofing them are used.

The noise from mechanical vibration is transmitted through the body-front structure and appears more in the front portion of the roof; in fact, a coupé or a small-compartment body seemingly will rumble worse than a larger one, and the roof will seem to vibrate in a narrow portion of the front. Some of the noise can be stopped by padding the front portion, perhaps between the first two ribs.

MR. MERCER:—The noise trouble in the body was overcome by one body-builder by changing the method of bolting the body to the frame. He said that he had put the first bolt close to the dash and had had considerable difficulty, but that he found that by putting the bolt back about 9 or 10 in. he had little or no trouble, because the front end was not fastened close to the engine supports.

MR. KERR:—To what body-maker does Mr. Mercer refer?

MR. MERCER:—Robbins, of Indianapolis.

MR. KERR:—My reason for asking is that I know of another company that originally fastened the body to the frame right at the dash, but it was found that the noise was reduced by attaching it about 8 in. back of the dash.

CHAIRMAN GODDARD:—I had a similar experience. I think it is because nearly everyone today uses a steel dash, if not a steel cowl. It is possibly on account of the effect of the three-point engine-support at about that point on the chassis frame and the tendency to stretch the dash like a drumhead; and also the fact that the dash is more or less a sounding-board and is closer to the engine than is any other approximately flat panel. Practically every motor car today has the steel dash, in which are corrugated ribs to stop the drumming effect. I think that fully one-half the drumming noise that is not in the roof is in the metal dash.

Returning to the types of construction or the constructional features that decrease the cost of the closed body, one of the important elements is, and always will be, quantity production, on account of the cost of floor-space. When all-steel body-construction cannot be used, the time-element must be reduced in some such manner as Mr. Mercer has described, by covering a body faster than it can be painted. Trimming in units and the bench assembling must be considered, so that the men shall not be in one another's way. Demountable construction must also be studied for the same reason that upholstery is made in sections.

A MEMBER:—Material always is the same; labor is always the same. The only way that the cost of bodies, except custom-made or special-made bodies, can be cut down is by making them as simple as possible. We can give a straight line to the outside but we must make the bodies as simple as possible and avoid all frills. That will tend to speed up production. The time saved by discontinuing fancy designs naturally will be put into the construction of many more bodies and will reduce the cost. Dispense with all moldings that can be dispensed with.

CHAIRMAN GODDARD:—Fad and fashion are making it easier every day. The easy-flowing line is backed by reason. It is easier to fabricate, is more pleasing to the eye, is less faddish and does not become tiresome; the buying public also is in favor of fabric at present. Everything tends toward helping the engineer solve the problem.

MR. HILL:—Have you had any expression of public opinion on the trimming of the inside of closed cars with artificial leather?

CHAIRMAN GODDARD:—There is a somewhat large difference of price between a sedan, trimmed in mohair velvet and painted and varnished on the outside, and the all-steel body. The all-steel body is enameled; it is black; the inside is trimmed with Spanish leather on the cushions and backs, and imitation leather on the sides. If the prices were equal, we might be able to determine whether there is a preference. The farmer wants a closed car just as much as the man in the city, and he wants to be able to use that car in emergency during the week. It is difficult to answer directly the question whether the public prefers leather, or hard-finished trim, to fabric. The reason for using mohair velvet is very similar to that for using leather. The car has a higher resale value. The biggest item in settling the appraisal value of a motor-car is the paint. Enamel finish answers the paint question. The inside is trimmed in fabric, which is nothing more or less than the outgrowth of the car-plush used by the railroads. There are objections to mohair, as there are to broadcloth and other woolen fabrics, and there are objections to leather, but the main reason we use it is utility.

H. B. DAY:—I am not an engineer nor a mechanic, but I had the first California top that was made. That was in 1916. The first fabric-covered car was in 1918; so that I have had over four years' experience with it. With regard to the cloth wrinkling, when some parts of the car were covered with wadding underneath the cloth, the fabric would work out and crack; and it made no difference what the fabric was. I have had fabric on the running-boards instead of linoleum, with a light-weight carpet between the board and the fabric. It worked well and did not wear out. It was cemented to the running-board, and is practically as good as new today. I have one car on which fabric has been in use for body-covering

for over 4 years and on which it is still in use. The car has been driven over 60,000 miles, including a trip to Philadelphia and back; and I think the roads I encountered in Arizona and Colorado were never so bad. The car has been out in the desert and in the snow, has been exposed to salt water and to the sun where we have 8 to 9 months of heat each year. The car looks nearly as well today as it did the day it was turned out. It has had no varnish.

As to the use of fabric for lining inside the car, that is commonly done on California tops. Its use is increasing. The fabric does not deteriorate and can be cleaned. A real California top will last as long as the car will last and will look well for 5 or 6 years.

L. L. WILLIAMS:—Why is the theory not advanced that, instead of mortising joints, the joints should be half-lapped and a screw sunk in? Glue costs a certain amount per pound. If a man is working on piece-work, he will not leave his bench to get fresh glue; he will put hot water into the glue he is using. Why not omit the glue and put in a screw, provided the screw is driven in with a screwdriver instead of being hit with a hammer.

We ought to get a definite idea of what can be done to produce a body at a minimum cost on a production basis in the way that the majority of builders necessarily produce bodies. They cannot continue to build bodies in the way they have been building them. The cost is prohibitive. I see no reason that makes it necessary on cars of a certain price to have a door that must lap three times to keep out possible draft, and put a weather strip inside it. You do not put a half-dozen jambs on the door of the tightest house ever built; you build a threshold for the door and fit the door to it. Of course, the door does not hop about as it does on a chassis.

I think it is the duty of the engineer to assert himself and say that he can cut the cost of a body if the sales department will sell it. If they cannot, then he must increase the cost of the body. If we are building bodies at a high cost, we can do anything we choose, but I think the cars we have in mind are those with closed bodies at a lower price. Why specify silvering quality plate-glass when, as a matter of fact, we will not have a bit of plate-glass in that specification?

On a very inexpensive closed body, I have seen as many as five screws driven into the top weather-strip of a door, when two, or at the most three, would hold it; and nails put into a panel 1½ in. apart, when we could not get the panel off if they were 4 in. apart. I think it is not necessary to build straight-sided bodies. A large part of them could be put on a rocker form and sent through a planer just as if they were straight.

CHAIRMAN GODDARD:—Mr. Williams has brought out a very important angle of the object of this meeting, namely, to discuss how the closed body can be made less expensive to use, not necessarily cheaper. Any one who brings out a very cheap body is likely to get a backkick from it. The body must function properly; it must be built on a framework; whether the framework is of steel or of wood, the joints must be made to withstand rough usage.

Mr. Williams brought up a point about rabbeting the door. We formerly used rabbets on the hinge on the sill-pillar and on the top rail. Now they have simmered down to the lock-pillar alone. It is possible to discontinue that rabbet and the expense of that machine operation. There are a great many points that have not been discussed thoroughly enough with reference to decreasing the cost of closed-body manufacture.

MR. STEINBECK:—Has not that question been answered by the making of bodies for cheap cars? Can we make cheap bodies and put them on high-grade automobiles? Are there not enough different classes of body made today to answer Mr. Williams' question? We can make them without rabbets. Taxicabs are made much more cheaply than limousines. All that sort of thing costs money. You could not put that kind of body on a cheap car, but you could put it on a high-grade car. We might take up the same question with the chassis. Why do we not get a chassis for a high-grade car at the same price as that of a chassis for a cheap car? Because quality is required from the chassis engineer as well as from the body engineer. So far as prices are concerned, speaking from the standpoint of a body-maker, I think they are low enough today, but it is true that we would like to get them lower and make a slightly greater percentage of profit.

CHAIRMAN GODDARD:—The whole matter goes back to the question of quantity production. I feel safe in saying that the Ford sedan body, or any other similar body that is made in similar quantities, is made more accurately than a body for the highest-priced chassis that ever was built. That is only possible through quantity production when the cost of jigs, tools, fixtures, dies, forms and the like can be spread over a large quantity. The cost will take care of itself when the quantity is specified; operations can be made more simply and more cheaply by increasing the equipment for performing them, but Mr. Williams at least has suggested things that might be done. We ought to consider the body purely from the standpoint of design, from the standpoint of what each particular part of the body does and what its function is. Decrease the number of joints, use a higher grade of lumber, perhaps, with lighter sections; in general, study body-construction purely from the standpoint of the functioning of each individual piece that goes into the structure.

THE HARDWOOD-LUMBER NEEDLESS WASTE

BY FREDERICK F. MURRAY

THE production of hardwood lumber has not kept pace with factory development, particularly that which has taken place in the automotive field. Some persons maintain that lumber is not susceptible to "development"; but all sorts and conditions of hardwood lumber are produced from the same tree and only a part is suitable for automotive construction. Some portions of the tree are far more suitable for furniture manufacture, while others are peculiarly adapted for use in parquetry and in building trim. Development, therefore, consists of properly differentiating the various kinds of material that come from the hardwood log so that the various industries may have at their disposal boards that have been properly classified. As the present system of grading has been in effect substantially without change for over a quarter of a century, years before the automobile came into general use, the grades originally established have little bearing upon automotive utility. Revised specifications for grading that would determine the major requirements, which in themselves include the secondary requirements, would on the whole obviate much of the waste that occurs under the present method.

Designating the grade in terms of the cut-up value

would provide a real and much needed simplification and avoid many existing inconsistencies. It would tend to discourage manipulation, the substitution of inferior grades and other irregular practices, that though reasonably infrequent are detrimental to the industry. Hardwood standardization is a component part of a general movement that involves all species of lumber, both softwood and hardwood, that is crystallizing in an organization recently instituted in the city of Washington and known as the Central Committee on Lumber Standards. This committee is endeavoring to produce a new and scientific grading-schedule that by common accord will establish a lasting instrument to be entitled the American Lumber Standards. [Printed in the January, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN G. W. KERR:—How would it be possible, by a change of the grading rules, to arrange things so that the body-builder will get more material out of the plank and the lumber producer more money out of the log? The title of this paper has brought the thought that a short-cut would be to have Mr. Hoover prevail on Congress to pass a law prohibiting the use of hardwood lumber in the building industry, and letting the furniture, automobile and agricultural implement industries have all the hardwood. These industries must have hardwood, but the building industry could get along very well without it.

The modern methods of cutting up lumber are exceedingly rapid, so much so that although the rate per hour of the workman and his earnings per day are probably three times what they were a decade ago, yet the output of pieces is much greater proportionately than the increase in the cost of getting them out. That fact probably leads to the use of first and second grades; whereas, some years ago, the manufacturer was inclined to buy rather more of the common grades.

F. F. MURRAY:—When I was in Memphis in 1922, I heard considerable discussion about making hardwood 2 x 4-in. lumber. That would be more or less of an innovation, backed solely by the idea of creating a better market for the low-grade hardwood stock. The 2 x 4-in. size made of yellow pine will allow any number of defects in the first grade, provided the 2 x 4 remains sound and the defects do not detract from the strength. By using a 2 x 4-in. size made of hardwood, which might have many knots or other defects, the member would then be even stronger than the 2 x 4-in. size made of soft wood.

Hardwood producers are also looking to the railroads for a greater consumption of low-grade hardwoods. Within the last year there has been considerable development in the use of gum ties. A few years ago, hewn cross-ties of white oak were specified. Possibly the only difficulties with the gum tie are that it must be treated within 2 weeks from the time it is cut, and that it should be cut when the sap is not flowing. By treating a gum tie immediately after it is cut, the incipient stages of decay are controlled and the tie has exceptional wearing qualities, defying mechanical wear and rot. The wooden cross-ties in the Pennsylvania terminal at New York City are of gum.

J. S. BURDICK:—What position does texture take in the grading program?

MR. MURRAY:—When we go into tabulation in the automotive field, we shall pay particular attention to the texture requirements and, judging from my brief experience in the factories at Detroit, production managers and engineers are not silent on that subject; so, I think we shall get plenty of data with respect to texture.

The producers are very anxious to serve the consumers in every possible way for the betterment of the trade, a reason that is, in effect, both philanthropic and selfish. The differences that have occurred have been due to a lack of understanding, and the data that this general lumber standardization seeks will be fully as illuminating to the producers as to the consumers. The producers have no exact idea of what the factory cut-up requirements are. Such information as the producers have at present has been obtained at second or third hand through the jobbers or the wholesalers, who are in more or less direct contact with the field, while only the larger producers have facilities to manage all of their sales directly with the consumer. Many expert salesmen who are traveling in the interest of lumber companies, either wholesale jobbers or producers, endeavor to learn what the particular requirements of each factory are, so that they can serve it with special lumber. That is doing what this movement proposes to do on a large scale.

AUTOMOBILE FINISHING-VARNISH

BY L. VALENTINE PULSIFER

AS the success or failure of the finish of an automobile depends largely on the finishing-varnish, a plea is made for more scientific analyses of the problems of automobile finishing and more care in selecting and applying a suitable varnish. The qualities to be desired in a finishing-varnish are divided into two classes: the shop qualities and the service qualities. The shop qualities include color, body or viscosity, working, flowing, setting, hardening, fulness and the safety of working. The service qualities, or those that enable the varnish to withstand the various conditions of use, include resistance to break-down under the chemical action of the actinic rays of sunlight, to the destructive action of moisture and the alkalis in mud and soap, to expansion and contraction, to vibration and to abrasion. The three most important factors in estimating the service-giving qualities of varnish are said to be elasticity, moisture-resistance and the film factor. Each of the various terms mentioned is carefully defined, analyzed and explained. Among the constants that must be determined, either for checking uniformity or for use as bases of tests, are the non-volatile content, which is the starting-point in the test for elasticity and in computing the film factor or thickness of the dried film; the ash, the flash-point, and the acid number. An empirical formula is derived by which the thickness of the dried film can be estimated with accuracy; and in a series of appendixes the details are given concerning tests for the drying, the safety of working, non-volatile content, ash, flash-point and acid number; the Kauri reduction test; and tests for moisture and alkali resistance. [Printed in the January, 1923, issue of THE JOURNAL.]

THE DISCUSSION

S. G. TILDEN:—Are any of the many body polishes on the market, either wax preparations or otherwise, worth considering?

L. V. PULSIFER:—So far as adding life to the varnish which many of these things claim to do, you may be sure they do not. In many cases, when they contain abrasive

or some dry-washing material, as they frequently do, with the idea of avoiding the washing of automobiles with water, they are destructive, because the operations, both of putting on and of washing off the polish, fill the surface with scratches that tend to break what we might call the selvage edge of the varnish. The varnish on old paint that has become dull can be increased in brilliancy by waxing, but it is no longer a varnish job; it is a wax job and, when it is done over, there is trouble. You can rub the varnish down and finish it but, if it has been waxed, to make the new finish adhere you must take the surface off and get down to the base.

CHAIRMAN G. W. KERR:—What influence has moisture in the varnish-room on drying?

MR. PULSIFER:—The drying of varnish is, of course, of a chemical nature. It is the chemical absorption of oxygen by a component of the varnish. A certain percentage of moisture, which varies with the temperature, will assist in the drying and is desirable to prevent the varnish from setting too rapidly. If there were no moisture, the thinner or the solvent in the varnish would be so great that the varnish would not set. On the other hand, it is possible to have too much moisture in the varnish-room, and I have known of cases where the cooling of the film condensed specks of moisture on the drying finish and caused pitting of the enamel.

CHAIRMAN KERR:—What is the percentage?

MR. PULSIFER:—That depends on very many factors. As a rule, a difference of about 20 deg. between the wet and dry-bulb temperatures is desirable. If the temperature is as high as 120 deg. fahr. with forced-drying systems, the wet-bulb temperature should be around 80 or 90 deg. fahr.

F. E. MCCLEARY:—Has much work been done with violet rays as a substitute for sunlight? Is there any use in working with them?

MR. PULSIFER:—The violet ray is produced by a form of lamp that is supposed to give off the maximum number of actinic rays that there is in sunlight. An attempt has been made to expose films to the action of violet rays and then to stretch the films by an apparatus arranged to give a uniform pull. The method thus far has been experimental. It has not been so successful as the Kauri reduction test and is much more complicated to make.

In the second place, the ratio between the time of action of the violet ray and the stretch that the varnish should show under a given test has not been established. The violet ray is used for the purpose of determining the permanent character of pigments, and for testing pigments that are to be used on inside-wall paints. An attempt has been made to use it on deteriorating varnish. Thus far the number of variables and the time necessary for carrying out the work have prohibited its use to any great extent.

HERBERT CHASE:—Is it feasible to secure a durable finish that is not lustrous, one without a high polish?

MR. PULSIFER:—There are two ways in current use for producing a durable finish that is not lustrous. One is the use of material similar to oil paint, containing so much pigment that no luster is apparent on drying; in other words, the particles of the pigment stick up to such an extent that there is no shine. Another way is to rub down a varnish, such as a chassis varnish, to a dull finish, after it has dried for 4 or 5 days. An attempt has been made to produce a varnish that would dry flat, but no varnish of this kind has shown durability; in other words, the material that must be added to the varnish to cause it to dry flat, destroys the life of the varnish and the varnish can be used only on cheap interior work. Rubbing the varnish down produces the better appearance of the two perhaps, but opinions differ as to that.

MR. CHASE:—Is the rubbed-down varnish durable?

MR. PULSIFER:—Yes, if the right kind of material is used. It frequently is not durable for the reason that an attempt is sometimes made to add enough rubbing-varnish to an ordinary body-varnish so that it can be used as a finishing coat. Rubbing-varnish has a much shorter life than finishing-varnish and adding 1 qt. of rubbing-varnish to 3 qt. of finishing varnish will reduce the life of the finish one-third. By using a material such as a chassis varnish, which dries so hard that two coats are required to get an adequate thickness, the work will last as long as if it were left bright. The durability is reduced by the amount that is rubbed off, and by the scratching of the film; but it is possible to get a satisfactory finish by that method, if the material is right.

MR. MCCLEARY:—Nothing has been said with reference to the hardness of the finish, which is a thing we are all interested in. Would the hardness affect the elasticity, or can that be obviated?

MR. PULSIFER:—The hardness of varnish is difficult to define. In the first place, a rubbing-varnish, as a rule, dries harder than a finishing-varnish, yet a rubbing-varnish is much more susceptible to abrasion. It is toughness that enables the varnish to resist abrasion. Frequently, a varnish that is called soft in drying will be the best, for the reason that it has this quality of toughness, which prevents the abrasive material from taking hold. It is toughness rather than hardness that prevents the rubbing that it gets while being washed from cutting the film. Hardness, of course, is absolutely the determining factor in many cases, when a certain production schedule is to be maintained and the body must be dry enough so that it can be hung at a certain time. The determining factor is the kind of material that is used, but if the results that are obtained from a varnish that dries too fast and too hard were better understood, perhaps more time would be allowed for the final application, and the day or two extra that would be required could be saved somewhere else along the line without slowing up the production speed. Any system that results in allowing more time for the application of the varnish will double the durability, if correctly used.

A method has been devised for testing the hardness of varnish by finding which one of a series of pencils, such as are made by the pencil companies, varying from 20 to 30 deg. in hardness and sharpened to a chisel point, will cut through a varnish-film that has been dried under certain conditions on certain metals. This is considered a measure of the hardness. It is a question in my mind which is the thing that counts, toughness or hardness. It is the toughness rather than the hardness, provided the varnish dries hard enough so that things will not stick to it. That is about the only requirement.

N. G. SHIDLE:—In the durability-rating chart, the varnish *D* is about six times that of varnish *A* in total points. Would the relative price of those two varnishes be 6 to 1?

MR. PULSIFER:—It probably would be 2 to 1.

MR. SHIDLE:—I notice the relation between the totals is 6 to 1, and you say that the resistance to exposure conditions is proportionate to the elasticity. That would make varnish *D*, 16 to 1.

MR. PULSIFER:—These two varnishes show two elasticities; one is extremely thin and extremely non-resistant to abrasives, while the other is extremely resistant to those abrasives. Other things being equal, the

elasticity would determine the durability. In this particular case there would be a wide range of resistance to moisture, which is the chief difference. The value of the moisture factor is complicated, and would vary in different climates.

CHAIRMAN KERR:—What is the cause of rusting under the varnish coat?

MR. PULSIFER:—If an automobile is painted properly, the coating, barring accidents such as cutting through, is about as tough as can be imagined. The pigment is very dense to the penetration of moisture, which means that if the finish is destroyed by rust from below, the rust must have been there in an incipient state before the primer was applied; and it is not always easy to determine whether the body is absolutely free of rust. Various methods for eliminating the possibility of rust on the surface have been devised, but the best of them will fail occasionally. This point cannot be attended to too carefully.

ALLEN KENDALL:—In the tests for turning varnish white, would there be the same action with salt water as with fresh water?

MR. PULSIFER:—Salt water, as a rule, is not so severe as is fresh water in turning varnish white. That is a thing not commonly understood. The water that will turn varnish white most rapidly is distilled water, which contains no alkali whatever. In an alkaline action, the alkali in the water will assist in breaking down the film. I suppose the idea came originally from the fact that vessels on the seacoast lose their varnish very readily, but that is on account of exposure rather than sea water. As a matter of fact, the water that causes the most damage to vessels is not seawater, but dew and fog, which consist, of course, of practically pure water. It is a bad thing to get salt on the deck and walk on it. The salt acts like any other abrasive. Salt water, by itself, has less effect on practically any grade of varnish than has pure rain water.

LAWS GOVERNING GASEOUS DETONATION

BY THOMAS MIDGLEY, JR., AND ROBERT JANEWAY

THE authors present in this paper an explanation of gaseous detonation based upon what are considered incontrovertible laws, and show by the functioning of these well understood natural laws that gaseous detonation is a phenomenon that does not require any hypothetical assumptions to account for its existence.

The physical conditions that must exist within an inclosed container when it is filled with an explosive mixture of gases and these gases are ignited are stated and analyzed mathematically, and an application of this analysis is made to the internal-combustion engine. The apparatus and the procedure are described, inclusive of photographs and charts, and it is shown how the formulas can be applied (*a*), for constant throttle and varying the temperature of the entering charge and (*b*), for constant temperature and varying the throttle opening and the compression-ratio. The results are illustrated and discussed in some detail.

Appendix 1 refers to the basic equations in the paper and has as its object the combination of these equations

$$P_1 - P_2 = W^2/g\ (V_2 - V_1)$$
$$W = KD_1^n T_1^m$$

into a single fundamental expression containing P_1 and P_2 as the only variables.

Appendix 2 is a mathematical determination of the critical pressure of detonation. [Printed in the April, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN H. L. HORNING:—With respect to Mr. Midgley's equations, remember that we have *K*, the coefficient of chemical reaction; times *D*, the density of the charge; times *T*, the absolute temperature; and that these are the three fundamental factors.

P. S. TICE:—Will Mr. Midgley explain Fig. 8 in further detail?

THOMAS MIDGLEY, JR.:—Fig. 8 shows the change in pressure with the variation of temperature. The sloping lines show the critical pressure at which detonation takes place, as the temperature is increased. Thus, as the temperature is increased from say 85 to 100 deg. fahr., *P*, the critical pressure at which detonation takes place, drops from around 220 to 198. At the same time, when we heat the manifold, we do not get any such drop-off of maximum pressure, because the drop-off of maximum pressure is only due to the slight reduction of volumetric efficiency.

A MEMBER:—In connection with Fig. 8, what fuels were you using? What was the tendency of the fuel to detonate as the specific gravity drops or as it increases?

MR. MIDGLEY:—We used only one fuel. A complete description of the fuel is given in Fig. 12. It was a kerosene. The temperature of 72.2 deg. fahr. for critical dissolution with aniline proves the fuel to have been of pure paraffin constitution. No comparisons have yet been made between two different fuels.

A MEMBER:—If crude oils of 28 to 38 deg. Baume are used as engine fuels, at what values will detonation occur?

MR. MIDGLEY:—That is one of the next steps in this work; also, to find out just what the anti-knock material added to a fuel affects.

A MEMBER:—The equations relating to detonation developed by Mr. Midgley relate only to the particular engine under consideration. The tendency to detonate would depend upon the relation of the fuel to the spark-plug. If the spark-plugs are located so that the distance of burning is short, the time must be short. If the time is limited, detonation cannot take place. So, it is possible to increase the pressure without having detonation by keeping that point always in mind.

MR. MIDGLEY:—That is right, within reasonable limits.

E. S. CHURCH:—Regarding detonation tube-experiments, the statement was made that the explosion ends up with a loud bang. Suppose the end of the tube was closed and the noise shut off from the end where the ignition started, would any noise have been perceptible to a person in the chamber where that end of the tube was located?

MR. MIDGLEY:—That has not been demonstrated experimentally, but everything we know about force indicates that the end of the tube would be distorted by having the high pressure hit it suddenly.

MR. CHURCH:—Then the speed of the detonation wave, somewhat approaching that of the sound wave, when striking the walls of the chamber, would have the effect of setting them into vibration; it would not be caused by the knock.

MR. MIDGLEY:—With an open tube, the sound is simply

a continuation. However, where we have something like a heavy iron wall to penetrate, the natural thing is to expect that it will be the distortion of the wall that will produce the sound, rather than that the actual sound will be transmitted. Consequently, the sound and the nature of the sound depend very largely upon the shape of the chamber that it strikes.

MR. CHURCH:—In Fig. 4, the waves of compression, traveling horizontally across that space, would produce an excessive pressure upon one side of the piston and not on the other. That might have several effects. It might have the effect of distorting the piston; it might have the appearance of producing a side slap on the piston. Now, if the location reduces the tendency to produce the ill effects of detonation, is not the ill effect of detonation due to that eccentric loading more than to any innate pressure?

MR. MIDGLEY:—No. Of course, the mechanical effects of detonation are influenced largely by where the detonation-wave strikes. A good heavy engine-construction will withstand considerable punishment without showing any noticeably ill effects. During the intense-luminosity period, there is an enormous amount of energy radiated as heat. I measured how much heat was radiated and how long it took. If that radiation were held constant for 1 sec., the top of the engine would melt. This loss is occurring right at the top of the stroke, when all the heat one can get is needed for the expansion stroke; consequently, this radiation loss, due to detonation, means a decided loss of both power and economy.

ALLEN KENDALL:—Your formula indicates that detonation takes place after a certain pressure. The statement was made that detonation is a matter of time. The pressure should rise to a certain point, regardless of the shape of the cylinder and regardless of the length of the flame. We do not get the same audible indications in the two cases.

MR. MIDGLEY:—The only explanation is that the critical pressure is reached before the velocity of the flame increases. Before the high pressure of detonation can be attained, the gas in this wave must become dense; but, before that gas can be crowded into that amount of space, the flame has to move an appreciable distance. The point at which detonation is set up is very sharp and, at that point, the flame suddenly jumps to a high velocity. Then the distance factor is involved. It has nothing to do with the equations themselves.

A. D. REESE:—In the expression for W, was the value for K determined experimentally; if so, was it determined at high pressures?

MR. MIDGLEY:—It has a meaning only if you accept this theory of the mechanism of detonation. The actual results obtained were used to determine the constants and the exponents. You can extrapolate from those if the theory of the mechanism is correct.

S. G. TILDEN:—Does the addition of an anti-knock compound postpone that point where the curve shoots up to the speed of sound or absolutely do away with it?

MR. MIDGLEY:—It postpones the effect. How much it is postponed depends upon the quantity of anti-knock material used.

DR. H. C. DICKINSON:—In reference to the effect of cylinder size and to distance of flame travel, will Mr. Midgley state, in the case of an explosion started in a tube 2 ft. long and another explosion started in a tube 1 ft. long, whether detonation in the two cases would occur at approximately the same relative position in the tube? In other words, are the shape and size factors taken care of by the equation in that way or not?

MR. MIDGLEY:—With regard to the tube experiments, if the length of the tube is increased, the tendency for it to detonate is increased because there is a longer column of gas to be moved. In tube experiments, we have found that we might have a tube 4 ft. long and no detonation; if we add 6 in. to the length of the tube, detonation will start at 3 ft. because of the added 6-in. column of air and the increased inertia.

DR. DICKINSON:—I refer to the experiments with the closed tube.

MR. MIDGLEY:—I do not know. According to the equation, detonation should occur at the same pressure, provided the same heat influences are present. At the point where detonation starts, however, the high pressure has not as yet, necessarily, been generated; a certain amount of shoving is necessary to compress the gas into the wave area. It probably takes a little distance to build that up. It might vary with the different sizes of bombs.

O. C. BERRY:—If, in a cylinder, the flame starts from a certain point and a flame-cap passes through the gaseous mixture, the temperature ahead of the flame-cap probably will be considerably below the burning temperature of the gas, and the temperature in the flame-cap will be very much above the burning temperature. Before this gas ahead of the flame-cap can burn, it must at least come up to the kindling temperature. Its ability to do that amount of work will depend upon how much energy it has to do that work with. We are told that there is a pressure-wave ahead of this flame-cap and, if that pressure-wave gets to be very high, we can see that the temperature in that pressure-wave will be raised, due to the heat of adiabatic compression. Has the problem been analyzed from the angle of associating the point at which the high rate of flame propagation sets in with the point where the temperature of this adiabatic compression gets up above that unstable condition in the temperature of the gases themselves?

MR. MIDGLEY:—There is no relation between that pressure and the auto-ignition point of the fuel. The auto-ignition point of the fuel is the temperature really necessary to cause the combination of oxygen and hydrocarbon with an instigator, with something right adjacent to it or corresponding to a point of the flame-front itself. The point at which the mixture becomes unstable instead of metastable is very much higher.

Mr. Berry also raises a question regarding the mechanism by which flame propagation is obtained. He brings up the fact that, in order for the next row of molecules to be affected, a certain amount of energy had to be given up by this flame-front. We feel we have some superficial evidence at least that the thing that determines the reaction velocity is how fast these molecules are breaking down, and not how fast they are combining with oxygen.

W. S. JAMES:—Prof. F. W. Stevens has been working at the Bureau of Standards on the flame velocities in gases, using two methods that are entirely independent. The results so far substantiate, in general, what Mr. Midgley has said. One of the methods used is known as the Bunsen-Guoy method. In this method the shape of the inner cone of a special bunsen burner is recorded photographically. When the entrance-gas velocity is known, the velocity at the surface of the cone, where the reaction is taking place, can he computed. At this surface, the gas velocity is equal to the flame velocity. In addition to this method, he has devised what he calls a constant-pressure bomb. That is nothing more or less than a soap bubble filled with explosive mixture of known proportions and fired from the center. The explosion

within the bubble is then photographed on a rotating film through a narrow slit. The outside of the original bubble is shown on the film for comparison with the final size. These two methods are entirely independent; but, in general, the results have been of a nature that confirms exactly what Mr. Midgley has said concerning the velocity rate when plotted against what might be termed the mixture-ratio.

L. H. POMEROY:—With respect to deposits on the outside of cylinders, I have attempted recently to measure the deposit on an aluminum water-cooled cylinder after 15,000 miles. Although small patches of scale a few thousandths of an inch in thickness could be observed here and there, in general, the slightest scratch with a knife blade revealed bright metal. As a non-conducting medium, I would lay odds on the deposit of oil mist, dust and decomposed floræ and faunæ on the fins of an air-cooled engine after the same mileage.

AN EXPERIMENTAL SURVEY OF GASOLINE AND KEROSENE CARBURETION

BY C. S. KEGERREIS AND G. A. YOUNG

REALIZING that great quantities of fuel are being wasted yearly by improper carburetion, the results of several investigations are assembled and considered from various viewpoints. Some pertinent data have been published previously; therefore, only a general discussion of gasoline carburetion requirements is presented in this paper. The scope of the paper is too broad to include a detailed discussion of any one subject. However, the data have been compiled to allow the graphs to explain many points that could not otherwise be touched.

The kerosene research is particularly valuable, not so much in outlining the requirements for burning kerosene as an automotive fuel exclusively, but for the carburetion requirements necessary in using our future petroleum fuels satisfactorily. Supposing that the future fuel will embody hydrocarbons boiling up to 550 deg. fahr. as a limit and containing sufficient volatile fractions to allow engine starting even in cold weather, the authors feel that kerosene will lie within the limits of efficient carburetion.

In addition to the ideal requirements, data are shown to prove the reasons for the present wastage of fuel. This is illustrated by the metering characteristics and allied data obtained from a few commercial carbureters, the data being used merely as a comparison with the ideal requirements. The change of temperature of fuel and air causes a change in the metering characteristics and the metering is not as desired. In addition, there are the temperature requirements of fuels that must be recognized, thus making the problem of carburetion truly complex. [Printed in the January, 1923, issue of THE JOURNAL.]

THE DISCUSSION

P. S. TICE:—There are several outstanding points regarding which my data differ considerably from those of Mr. Kegerreis. If we compare gasoline and kerosene in the same engine, with equal charge temperatures and substantially no fuel liquid on the manifold wall in either case, the mean-effective pressures and the thermal efficiencies are found to be almost exactly equal, with a slightly less exhaust-heat loss and proportionately greater loss in the jacket for the kerosene, if there is no detonation. This statement is substantiated by work with four different engines in which the work was done very carefully and thoroughly. If we continue this direct experimental comparison of the two fuels, the mixture-ratios for maximum power and for maximum thermal efficiency seem to differ only as the calorific values differ; that is, the kerosene mixture is slightly leaner than the gasoline mixture.

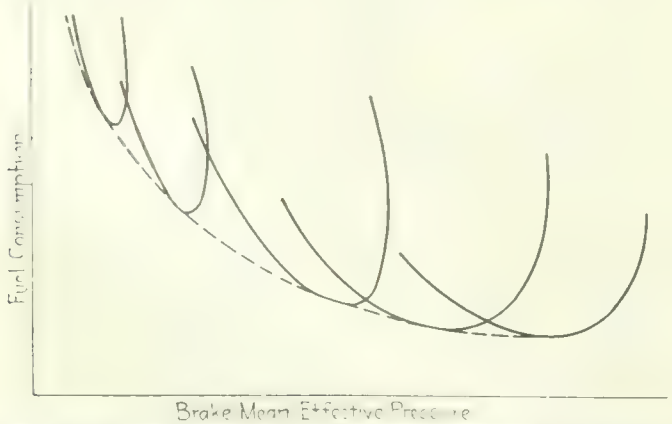

FIG. 40—CURVES SHOWING THE RELATION BETWEEN THE BRAKE SPECIFIC FUEL-CONSUMPTION AND THE BRAKE MEAN-EFFECTIVE PRESSURE

I find that the maximum efficiency is not obtained at the lower limit of regular inflammability, as stated by Mr. Kegerreis. It seems that he must have arrived at this conclusion as a result of the natural limitations of his method of preparing the charge, since his limits throughout represent more fuel in the charge than the proportions found to give maximum efficiency. The characteristic graphs, Figs. 40 to 43, show what I mean.

In Fig. 40, we have a plot of brake specific fuel-consumption against brake mean-effective pressure, covering the whole load range at a constant speed. Each one of this family of curves represents a constant manifold-pressure and, therefore, a substantially constant amount of air pumped by the engine. In each curve, the right-hand end represents the richest mixture that was used, and the left-hand end the leanest mixture that would fire regularly. No attempt was made to define the regular combustion limit on the rich end, although it was accurately defined at the lean end. Obviously, the envelope curve, shown dotted in Fig. 40, represents at any output the minimum possible specific fuel-consumption under the conditions of the runs. The point I want to make is that the mixture values at the lower limit of inflammability for regular engine operation are widely spaced from those giving optimum economy. My work shows fairly consistently, with either gasoline or kerosene, that the lower limit of regular inflammability is about 0.0445 according to Mr. Kegerreis' method of stating mixture proportions; that is, about 22.5 to 1, the way the rest of us state it.

Experimental examination of a considerable number of engines shows that the relationships between optimum mixture proportions and relative load are independent of the engine speed in well designed engines in which the valve-timings are not too much distorted from best values at either end of the speed range. A plot of substantially the most economical air-fuel ratio values for a typical car engine is shown in Fig. 41.

As is well known, mixture strengths resulting in least specific fuel-consumption do not deliver the maximum

power at open throttle. At the same time, there is no object in running with maximum-power mixtures when maximum power is not demanded; that is, optimum metering characteristics in a carbureter will maintain the minimum-consumption mixture-proportion throughout the greater part of the load range, and will enrich the mixture to cause maximum power delivery as full load is closely approached. This desired change in the air-fuel ratio is shown by the dotted curve at the full-load end of Fig. 41.

It is interesting to combine the level-road engine-load versus car-speed curve as in Fig. 42, with the optimum air-fuel ratio versus relative-load curve, as in Fig. 41. For several reasons, the "relative" load is, in car operation, slightly less at some speed higher than the minimum or idling speed of the car. Combining these curves gives the optimum air-fuel ratio versus level-road car-speed curve having the characteristic shape shown in Fig. 43.

C. S. KEGERREIS:—In regard to the mixture-ratios required for maximum thermal efficiency, Mr. Tice criticizes the results in the paper based on the given power basis and then, in presenting his data, he discusses the problem from the load or constant-manifold-vacuum viewpoint. The two methods are entirely different and,

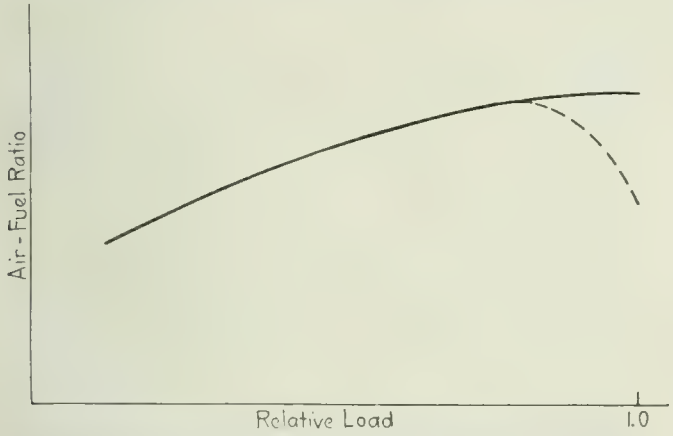

FIG. 41—CURVE OF SUBSTANTIALLY THE MOST ECONOMICAL MIXTURE-RATIO VALUES FOR A TYPICAL CAR ENGINE

if Mr. Tice will review the paper, I think he will recognize the error in his comparison.

The lean limit of inflammability will vary somewhat in different engines and also with the method of hot-spotting the manifold. In the tests that Mr. Tice reports, a limit of 0.0445, or 22.5 to 1, is exceptionally lean and is rather extraordinary if this limit is a constant with respect to the engine load. I have recorded data from a few engines that show the limit as low as 0.0400, or 25 to 1, but the limit was not constant for the load and is entirely beyond the average line for the usual engine. It certainly is gratifying to find Mr. Tice's data checking so closely with those reported in the paper under the heading of mixture requirements for change of engine speed.

In developing a relationship between the car-speed for level-road operation, and the optimum mixture-ratios, a general characteristic curve can be drawn, but this curve will change for each individual car. It is true that in many cars the idling speed does require a higher "relative" load than some higher speed, but this relative load is a variable for different cars at the same speed. Thus, as the engine load affects the ideal ratios, the ideal mixture-requirements will vary in value at the same speed

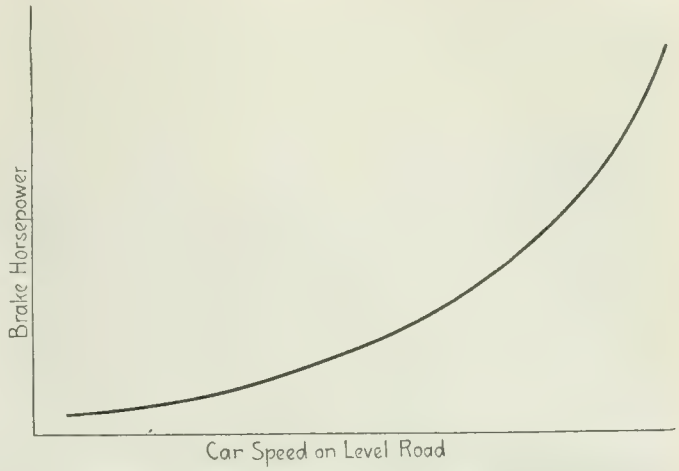

FIG. 42—CURVE OF THE LEVEL-ROAD ENGINE-LOAD PLOTTED AGAINST THE CAR SPEED ON A LEVEL ROAD

for each individual car. Given a certain engine, the car weight, the wheel diameter and the gear ratio will determine mainly this relative load at the lower level-road car-speeds.

H. S. MCDEWELL:—Were the inlet-air temperatures of the mixture above the carbureter taken? The method of obtaining reproducibility by an orifice plate between the carbureter and the manifold, while fine from the standpoint of reproducibility, does not give actual operating carburetion conditions due to the fact that there is an obstruction in the system totally different from that of the usual throttle. As a result, there is not the usual distortion and, consequently, not the usual effect on the liquid distribution; in fact, there may be some reatomizing effect from the fact that the usual creep of liquid along the side walls will be caught at the throttle plate and may be reatomized at the edge.

The so-called carbureter-testing plant is the most deceptive apparatus that ever was built. It gives a beautiful comparison between two different carbureters under steady-flow conditions, but they are not engine conditions. The biggest change from engine conditions is the fact that, while there may be artificial pulsations in the flow, they are not the actual reversal of flow or flow-back conditions in an actual engine.

MR. KEGERREIS:—The inlet-air and the mixture temperatures were taken in all cases; some are presented in Fig. 25 of the paper. The use of an orifice between the carbureter and the manifold, with the throttle removed,

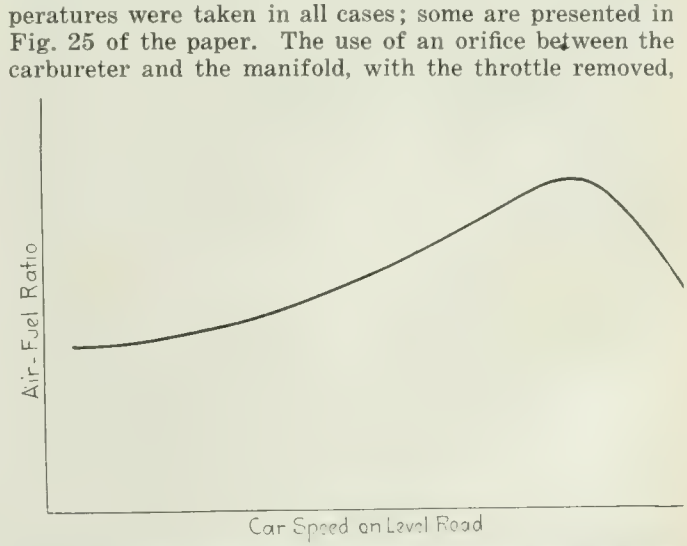

FIG. 43—CURVE GIVING THE RELATION BETWEEN THE OPTIMUM MIXTURE-RATIO AND THE LEVEL-ROAD CAR-SPEED OBTAINED BY COMBINING THE CURVES OF FIGS. 41 AND 42

probably changes the conditions somewhat. With the carbureter used, the atomization at idling was probably not as fine as if the throttle had been in place. The big improvement over the butterfly throttle-operated job is that there is no feathering of the charge into either leg of the manifold.

In discussing the accuracy of the carbureter testing-plant as compared to engine conditions, I think it can be stated that no one has ever determined conclusively the exact difference between the two. In this particular case, carbureters have been run in the plant and on the engine. Comparing the tests, for example, when using the carbureters whose characteristic curves are given in Figs. 34 and 36, the same characteristic curve is obtained on either plant and at nearly the same flow-rates. It is absolutely admitted that the pulsations in the two cases are not comparable, but whether the error is of an appreciable magnitude must be established by further investigation.

E. H. SHERBONDY:—There are two things a carbureter does; it meters the fuel and the air, and it diffuses the fuel throughout the air. So, we have various kinds of choke and spraying devices, to get the fuel into the air. Two years ago I was developing a powerplant to get its utmost performance. We wanted to get mean-effective pressures for a motor-car engine that were comparable with those commonly secured in aircraft engines; we wanted to get flexibility and silent operation, manifold depressions that would be similar to those for aircraft-engine carbureter-operation, since an aircraft engine is called upon to run at fairly high speed all the time. I built a system of this kind, using an air-meter and experimenting to find out why the pressure drops were so enormous, and why so much pressure was lost in the air passing through the carbureter. All that is required is to have a pressure drop great enough to atomize the fuel. I found, for instance, that with a 1½-in. carbureter, with a properly designed air-chamber below the venturi tube, I could pass the same number of cubic feet through a 1¼-in. carbureter that I could get through any 1¾-in. carbureter made in America.

MR. KEGERREIS:—The explanation by Mr. Sherbondy of the critical point where the high frictional loss was found may be the cause in some carbureter bodies. The case of the carbureter, the results from which are represented in Fig. 34, is somewhat different. The elbow was removed, allowing the ends of the venturi and the nozzle to be the limiting factors. The same frictional loss was present whether the elbow was in place or removed. The nozzle was next removed, allowing only the venturi to remain in the airstream; then, of course, the frictional loss dropped to a rather low value. This information was procured at a high flow-rate through the carbureter. It is interesting to note that, in carbureter bodies, the placing of the choke valve is important. On a new experimental model I am developing, no choke was originally employed. No other change was made except to add the ordinary choke valve positioned at a certain angle. The result was that the airflow was increased 10 per cent.

J. G. WILLET:—An important fuel loss has been overlooked. When a car reduces speed quickly, as in approaching a corner in traffic, the accelerator is released and the engine is being driven by the car; the result is that the engine is being fed an over-rich mixture. This is noticeable when the car is accelerated, on account of the usual black smoky exhaust shown at the time. It not only wastes fuel, but it deposits carbon and tends to dilute the lubricating oil. Could not these troubles be overcome entirely by a system in which the fuel delivered to the engine by the carbureter is controlled by the pressure developed in the engine cylinders, which corresponds with the load on the engine? Such a method would not only vary the fuel delivered to the engine in exact proportion to its load, but would cut it off entirely when the engine was being motored by the car.

MR. TICE:—In further discussion of the point just brought up, the conclusion that an examination of Mr. Kegerreis' work leads to is that the variation in the strength of the mixture must be made with the load, not with car speed or engine speed or rate of airflow. As to the matter of a mixture being too rich under one operating condition and too lean under another, that represents nothing more than the fuel lag that we have to put up with in our present commercial intake-manifold. To have the manifold deliver to the engine the mixtures that are delivered to the manifold by the carbureter, there must be certain amounts and varying quantities of liquid in the manifold and on its walls. So long as an intake system makes it necessary for that to happen, just so long will we have widely changing mixture proportions every time we change the throttle position.

CHESTER S. RICKER:—Many of those present will remember driving cars in which this film on the walls of the manifold that Mr. Tice mentions might be left there when the car is running forward. I remember a car that was built 10 years ago with clutches that would only drive in one direction. If the car started to coast, it coasted as though it had a coaster-brake on it; the engine maintained whatever speed it had or slowed down gradually. If this condition exists, as these carbureter men suggest, I am wondering whether that might not be considered as a mechanical development to assist the car in gaining the maximum economy?

W. L. DEMPSEY:—The engine people have as much right to improve the engine as the carbureter people have to improve the carbureter, and I believe we can get a real insight into our troubles if we will stop for a moment and analyze the Diesel engine. The Diesel engine does not waste any fuel in the crankcase. It is the most economical of all of our engines, and it will burn practically anything that is put into it. What is the fundamental reason why the Diesel engine, operating as it does under all conditions on practically any grade of fuel, does so without any wastage into the crankcase? I believe it would not be fair to say it is the fault of the carbureter, because the Diesel engine has no carbureter. From the time the fuel goes into the Diesel engine until it is completely burned and exhausted, the temperature never drops below about 900 to 950 deg. fahr. There is always an excess of oxygen in the Diesel engine. The fuel of the engine is made up of the petroleum spheres which grow like a bunch of grapes; it is represented by CH_2, or 1 atom of carbon and 2 atoms of hydrogen. Every time we add 2 atoms of hydrogen and 1 atom of carbon, the boiling point of that particular molecule, if we consider those between CH_2 and C_2H_6 or on up the line as the molecules enlarge, increases about 60 deg. fahr. It is not only necessary that this molecule be broken up before the carbon and the hydrogen can be free to unite with the oxygen of the air to make complete combustion, it is not only necessary that the temperature be brought up to a point where the energy that is given to the atom by heating it is stronger or greater than the natural affinity of each atom for the other, but it must be maintained at that temperature during the whole time that the fuel is in the process of combustion; otherwise, whenever it drops below that critical temperature it must necessarily condense, and we will make a complete mixture in the

carbureter and condense it before we get it into the cylinder.

If one watches any well-made manometer and varies the throttle, this will vary the compression, and if one varies the compression this will vary the temperature of compression. To my mind, the reason that the Otto cycle, with its throttle-governed system, burns more fuel per horsepower than the Diesel engine, is because it wastes more fuel into the carbureter because the temperature has dropped. It is all right to talk about fogs, but you cannot explode a fog. You never get combustion and explosion until you get a dry gas; and, whenever the temperature drops below the temperature of the dry gas, that amount of fuel is bound to exhaust. The only way to get efficient carburetion out of the fuel is to mix it with the air and get the atoms into as close proximity as possible. A peck of potatoes comprises large and small potatoes and, when they are baked in an oven, the large ones require more heat than the small ones. We have the same situation here; it takes a little heat to vaporize the smaller particles and a greater amount of heat to vaporize the larger ones. If we can devise some scheme to maintain the temperature at 250 deg. fahr. through the carbureter, we will get economy at that; but if we maintain the temperature from the time the air strikes the carbureter until the time the compression is completed, we will increase the economy. Therefore, if we can maintain a uniform compression in the engine and if we can make it impossible for the fuel, the liquid, the spray or the fog, to touch a water-jacketed wall that cannot be much above 212 deg. fahr., we will help to solve this difficulty. We cannot very well keep a dry gas of molecules that requires a temperature of 500 deg. fahr. to vaporize them by spraying fuel against a water-jacketed wall that has a temperature of 250 deg. fahr.

Two important things must be improved in an engine. First, it must be furnished with sufficient oxygen to have 1 atom of oxygen for each 2 atoms of hydrogen, and 2 atoms of oxygen for each 1 atom of carbon. Second, the temperature must be maintained from the time it enters the cylinder until the end of the compression stroke. By so doing the economy will have increased decidedly, and the engine will burn practically anything that is put into it.

A. D. T. LIBBY:—Did Mr. Kegerreis, in these experiments with kerosene, make any attempt or experiments to feed superheated steam into the engine simultaneously with the kerosene mixture?

MR. KEGERREIS:—In these experiments the compression-ratio used was about 4.6. At 70 lb. per sq. in. it gave some detonation, of course. We used no water whatever; they were pure kerosene and atmospheric air mixtures.

NEIL MACCOULL:—What experience has Mr. Kegerreis had in measuring mixture temperatures? In Fig. 25, he shows a maximum temperature drop of about 50 deg. fahr. between the temperature of the air going into the carbureter and the temperature of the mixture, when the air going in is at 250 deg. fahr. In some experiments we have made, we have tried measuring the temperatures of the mixtures at the various points in the manifold. At every place we put the thermometer, we got a different temperature, but we found the minimum temperature drop with "motor gasoline" to be more than 100 deg. fahr. with air supplied to the carbureter at 250 deg. fahr. We are conscious of the fact that there are wet-bulb conditions going on in measuring the temperature of the mixture, but if vaporization proceeded to a point where the mixture is saturated, one would assume that a wet bulb should not give a temperature below that of the actual air and fuel mixture.

During these runs, was the spark kept at a constant advance or was it advanced in each different test to give the maximum power?

MR. KEGERREIS:—The mixture temperature was measured approximately about 10 in., I should imagine, from the carbureter; that is, the mixture went around a 90-deg. bend between the thermometer and the carbureter.

The conditions of spark-advance with respect to temperature were constant. With respect to load, of course, they were necessarily held for high-power conditions in all cases, and that meant some retardation at the higher loads; not so very much, but some. Also at the maximum load, 100 per cent load, some diethyl selenide was used to suppress the detonation. I think you will find, with respect to detonation, that one of the curves will show its effect on the power at the higher temperatures and the half-load condition.

F. C. MOCK:—The conclusions of the paper as to fuel mixture requirements are, in general, those held by our own engineering organization for a number of years, and their accuracy has been proved by many tests, on a great number of engines. We find, however, and I believe this will agree with the observation of many of our members, that the exact requirements of mixture proportion are different with each design of engine; as a matter of fact, they may be different with the same engine at different times in its service. Probably at the highest mixture temperatures reached during the test described in the paper, and certainly at the lower temperatures under which passenger-car engines operate most of the time, there is a definite portion of the fuel unvaporized in the intake-manifold and distributed to the various cylinders with a degree of inequality depending upon manifold contours, air velocity, the temperature and the volatility of the fuel. The requirements of mixture delivery from the carbureter for best engine operation will, of course, vary with this inequality of distribution. The quality of the mixture leaving the carbureter can easily be different from that received by a given cylinder, and the carbureter setting must always be a compromise that will average up best among the different cylinders.

The result of all this is that a considerable amount of experimental work is necessary for best results from a given engine. First, in finding the mixture requirements, then in setting the carbureter to comply therewith. The idea of a "mail-order" carbureter, which could be furnished, with fixed adjustment, from specification of the bore, stroke and number of cylinders of the engine, never has been and never will be practical. Given, however, complete information as to an engine's requirements, I am very sure that carbureters can today be obtained which will come much nearer meeting these requirements than the authors of the paper seem to believe.

I am rather certain that it will never be desirable to do away with adjustments on a carbureter for passenger-car service. This is not on account of the variation in the mixture delivery with the temperature, for this, even according to the values given in the paper, amounts only to about 3 per cent or perhaps ½ mile per gal. on either side of an average setting, for a 100-deg. fahr. temperature change. Such a change is minor in comparison with the change in the fuel requirements of the engine for good acceleration, or for full power at low speed, under a 100-deg. fahr. temperature change, or at constant temperature with different fuels that can be bought from adjacent filling stations in many of our cities.

Since the required adjustment is dependent upon fuel characteristics as well as upon temperature, any thermal adjustment on the fuel-jet, set and locked at the factory, will probably waste as much fuel as it saves on cars in general service. A successful automatic control of the fuel-jet would have to be so intelligent that it would function according to the intake-manifold temperature, the engine temperature, the entering-air temperature, the manifold vacuum, the manifold velocity and *the volatility and the viscosity of the gasoline.*

MR. KEGERREIS:—Mr. Mock's discussion is very timely and, being presented by a representative of a large commercial carbureter company, where the results, no doubt, were procured largely from actual car installations as well as from laboratory work, they bear out the general findings of our researches conducted wholly in the laboratory. I am sorry Mr. Mock seemingly has taken for granted that the few instances cited in the paper cover the results of all the carbureters observed on the testing plant. However, it can be stated, that, knowing the complete engine requirements, there are very few devices that will approximate the ideal. These data will be published in complete form at a later date.

In connection with the discussion of the automatic control of the fuel-jet, it is fairly certain that a jet can be designed such that it will inherently compensate for the entering-air temperature and the viscosity of the particular grade of fuel that is being used.

COORDINATION OF THE MOTORBUS AND THE STREET RAILWAY

(*Concluded from p.* 436)

the full support of the public, has required that it be assured against losses from operation in territory where there are not enough inhabitants to guarantee a return upon the money invested in the extension. In Baltimore we have a similar situation. The requirement by the railways that they be assured against loss when they give service that is designed primarily to increase the value of somebody else's holdings, is a perfectly just and reasonable one.

MOTORBUSES AS RAILWAY AUXILIARIES.

The development of a motorbus that can be operated at the minimum of expense, will make it easier for people living some distance from a rail line to get transportation, although at a higher price than is charged for rail service. By extending motorbus lines from the termini of rail lines or from other points into sparsely settled territory, railways are enabled to serve sections that could not hope for rail service for many years to come. When the railway does this, the people are assured of a permanent service and property owners are encouraged to build homes. As the district grows, the time comes when service can be given more cheaply by the railway and then the railway company is justified in extending its rail lines into districts that have been built up by motorbuses, transferring the buses to still more remote sections. When such territory is served by individuals or unregulated drivers, the community has no assurance that the service will be permanent. A fly-by-night jitney driver may be able to serve a community for a limited time at a low fare, but his day is short and, when it is done, the people find themselves marooned unless the railway company, with its years of experience, comes to their rescue.

I could quote from many reports and present many arguments on this subject, but I know that you are well aware of the facts. Let me say in closing that the prosperity, comfort, convenience and intellectual growth of the people depend primarily upon the establishment and maintenance of a transportation service that is reliable, permanent and efficiently conducted. There has not yet been developed any transportation service of this character, except that of the steam railroads and the electric railways. As a representative of the electric-railway industry I want to say that my industry recognizes the great service that can be rendered through the use of motor vehicles, and that it is using them and will use more of them in the future; but further, that any policy of competition which unwise automobile advocates may adopt is certain to be ruinous to themselves and to the railways, whether they be steam or electric; and once a railway stops operating it is extremely difficult to restore the service.

I trust that I have made clear to you in this discussion the fact that if your great industry and the electric-railway industry will cooperate, far greater benefit will flow not only to us, but, what is more important, to the public that we serve.

The Retailer and the Engineer

By Harold B. Wess[1]

Cleveland Automotive Transportation Meeting Paper

THE author recognizes the engineer as the proper medium of an effective control in industry because he has the power to visualize minutely, in advance, the product as it will appear and operate when completed, to think and to plan on paper and to adhere to accurate mathematical thinking in making decisions as well as in the conduct of his operations. He states that these qualifications can be applied to advantage in any branch of a retail organization today.

The application of engineering principles to retail-organization management is discussed and the expense sheet of retail business is mentioned as being the point of contact at which the automotive engineer can assist the retailer in reducing operating costs by improving delivery service. The author suggests automotive concentration upon the construction of an improved light parcel-delivery truck, as well as one of heavier type for delivering merchandise in bulk and transporting furniture.

AS engineers you, to my mind, represent the constituent of industry that is being recognized as the proper medium of an effective control over the ever-expanding organization problems. Whether the engineer has been trained along electrical, automotive or civil lines, or any other form of construction and planning, he has essentially those qualities that are most needed in industry today. He has the power to

(1) Visualize minutely, in advance, the product as it will appear and operate when completed

(2) Think, and plan on paper

(3) Adhere to accurate mathematical thinking in making decisions as well as in the conduct of his operations

In any branch of a retail organization today, it is evident how essential these three qualifications are, and the engineer is especially trained to fulfill them.

Let us consider the merchandising branch. What do we find? When the retailer's business was small and the individual merchandise man could keep in close physical touch with every item on his shelves, all was well. When merchandise increased to such unusual volume as to make such intimate contact impossible for him, he had to resort to the engineering method. Therefore, the progressive merchant outlines on paper a complete plan of what his stock should normally look like from month to month, not in dollars and cents, but in physical units. Just as the engineer reassures himself by referring from his machine to his plan, so the merchandise man always refers from his actual stock conditions to the plan that he carefully drew up. In all of his operations, he is more and more beginning to visualize his sales, his stock and his turnover, with the same mathematical accuracy and the same graphic and mechanical methods as those employed by the engineer. As the engineer sets up accurate mechanical devices to guard against too high or too low a temperature, to make sure that he is not caught unawares and probably too late to replenish or adjust his machine, so the progressive merchandise man sets up similar reliable safeguards by which he knows daily whether he is running short in any of many hundreds of rapidly selling items, or whether he is being over-stocked in any of the slow moving or staple articles. He does not order items blindly; like the engineer, he refers to his prepared plans and builds his business structure in accordance with them.

Application of Engineering Principles

If we take any other branch of the retail organization we will find that this engineering method is being applied. Peculiarly enough, this engineering method, or what I should prefer to call engineering psychology, is much more used in the so-called non-merchandising departments in the retail organization. As yet, it has not fully invaded, or made itself felt as a motivating force in merchandising problems; but there is no question that the time is coming when the merchandise man will find that the "walking delegate" form of executive control will be inadequate. He will find himself in the same position as a teacher who tries to keep 100 children all together and in step. When the teacher runs up to the front of the line and tries to adjust the pupils, the rear is disorganized and, by the time he returns to the rear and attempts to bring them into step, the front is out of step and in disorder. So, the inexperienced teacher keeps running up and down in a frantic effort to have a completely organized marching unit, with no other reward than aching feet. The walking-delegate type of executive is in the same position. Just as he has adjusted one difficulty in his organization and plugged up one hole, behold, another trouble is started. The reason is very simple. It is all due to the fact that the operating control does not emanate from a centrally conceived idea. The various sections or units do not tie-up into one central point.

Imagine a ship on the ocean guided from several different points, each directing it at will, instead of being controlled by one radio station. It would be a very wabbly ship, and what applies to it usually applies with equal force, figuratively speaking, to the wabbly ship of industry, or to any part of an organization. Only he can truly be called an executive of the highest order who adopts the engineering method, carefully controlling his organization from an organized plan, built up with mathematical precision; a man who is guided by this plan just as the captain of a ship is guided by a compass; one who can control the movement of his ship of organization with the same certainty as if he had concentrated all the engineering energy within one central radio station.

You are automotive engineers but, because you are *engineers*, I know that, whether I talk on retailing or on any other branch of industry, you will apply to it a mode of thinking that is bound to be well balanced, accurate and reliable.

Department Store Expense

I invite you to take your place on the expense sheet of the retail business, because it is the sheet on which the retailer is concentrating all his energies today. It is the sheet on which the retailer is expending sums of money that might well go into his own profits, if it were not for the fact that he wishes to cut down the expense so

[1] R. H. Macy & Co., Inc., New York City. Chairman of the Retail Distribution Association.

that the public will benefit. The retailer was attacked severely in regard to high prices in 1920 and 1921, but the true state of affairs, as reported by the Bureau of Business Research of Harvard University, was that department stores earned 1.7 cents per dollar of sales during 1920, and 1.3 cents per dollar of sales during 1921. An analysis of earnings of similar kinds of business shows that the department store is one of the lowest on the scale. That is inherent in the requirements of department-store service.

The chain store can earn 10 cents per dollar because its service to the consumer is at a minimum. That is equally true of many other forms of distribution to the public. The department store, however, must render a high type of service and, in its effort to give a minimum price to the public at the same time, it is bound to get a lower return for its selling dollar than is true in many another form of distribution.

Automotive engineers are in a position to help the retailer bring down his costs of operation in one particular form of service. I can speak for our own store, and point to the great efforts being made to analyze our various operations so as to increase their efficiency, all being with a view toward decreasing our costs and giving that benefit to the public. For instance, we conducted and are still conducting an investigation in our delivery branch of service, in which you are particularly interested. We sent out four trained college men who have spent months on the delivery wagons in analyzing very accurately, with stop-watches, every possible motion made during the day in the various phases of delivery operation. Thousands of repetitions of each motion were recorded and, when all of the data were gathered and studied, we were able to arrive at some fundamental conclusions. We are still looking forward to developing some very valuable standards to guide us in operating our delivery service with a maximum of service to the customer, and with a minimum of expense to the store and to the customer. We are doing that in every branch of our business. We are applying the engineering method. However, when we come to use equipment and supplies for our service that we are bound to purchase from others, we have no control over them. We may expend a great amount of money to determine the best methods of operation and to find out how to save here and there.

When a store like ours invests its energies and its money for the improvement of methods and for the saving of operating expenses, it is not only doing so for the business and for its customers but, by conventions and through publications, it is contributing to other organizations the information that it has gained by its own efforts. If every retailer and if other organizations followed the same policy, and many of them are doing so, we can see easily what an important motivating power such approach in modern business would become and what a powerful force for placing modern industry on so efficient a basis as to make it impregnable to the criticism of the most radical in our social organization. We could bring modern industry to an efficiency that would cause the public, which now and then is amenable to certain prejudices, gradually to develop much confidence in the retailer. The public would soon realize that the retailer had reduced the cost of service that the customer wants.

Types of Vehicle Desirable

As to the place of automotive engineers on our expense sheet, we can do much to improve our methods and reduce our overhead but, when we are confronted with materials that we must purchase from the outside, we have a right to tell these people that we are expending all our energies and utilizing our resources for the reduction of our overhead cost, and to say that we expect them to do the same for us insofar as the supplies and equipment we purchase from them are concerned.

The retail field today is not only applying its best efforts individually to improve its operating methods but, collectively, it has organized toward the same end. For example, the National Retail Dry Goods Association, an organization built-up for the purpose of placing retailing in the foremost position in modern industry, through its operating associate groups, is not only helping to build the highest form of retail organization, but it is making its contribution to other industries. If we consider, for instance, the Controller's Congress, an associate group of the National Retail Dry Goods Association, we find that the accounting system it has just developed has created such active interest among industries outside of the retail field that it is rapidly being adopted in one form or another by others. A group that is of greater interest to automotive engineers is the International Retail Delivery Association, which is now affiliated with the National Retail Dry Goods Association, as an associate. Here we meet annually to find ways and means of reducing the expense of operating our delivery system.

There is one expense, however, that we cannot reduce without your assistance, and that is the expense as it particularly applies to the motor vehicle. How much study have you really given to the problem of the department store as it applies to the motor vehicle? Can you honestly and truly say that you have built a motor vehicle to fit the needs of the retail field? The express company and the shipping company uses its vehicle to deliver merchandise that is mostly heavy. Its stops are certainly not short. I know of no other industry that has the problem of house-to-house delivery, where mileage is really a minor factor. I know of no other industry where a certain phase of its delivery equipment is concerned with merchandise, where weight is a small factor. I could continue to mention the particular differences between the retail requirements of the motor vehicle and that of other industries. Has a real study been made of the requirements of the retail field so that a truck can be constructed that is in every respect a retail truck? I hope I am wrong but, from my discussions on this subject with men in the field, I think that has not been done, or certainly not to the extent that the importance of the problem warrants.

Recently, I spoke of the need of placing on a truck a body that is essentially a retail body. Such a body would reduce sorting and loading operations and would assist materially in an efficient delivery. So far, no effort has been made to experiment particularly with a delivery body. My intention is to appoint an Automotive Construction Committee from among the members of our Association, who, because of their particular training along these lines, and with the assistance and cooperation of our entire membership, will present to you what they think are the particular requirements of the construction of a light parcel-delivery truck, as well as of a heavier type needed for bulk and furniture deliveries. With your engineering training and application, and your cooperation, so directed, these vehicles should produce results that would cause you to feel that you have assisted the retailer materially in bringing down his expense.

Successful Tractor and Semi-Trailer Railroad-Terminal Haulage

By J. F. Murphy[1]

Cleveland Automotive Transportation Meeting Paper — *Illustrated with* Photographs

THE author describes a system of automotive transportation for intra-city hauling and the movement of merchandise between railroad terminals that has enabled the company he represents to serve the city of St. Louis and the railroad terminals there with a high degree of efficiency through the utilization of tractor and semi-trailer units and a thorough supervision of their movements. The units are described and illustrated, and the conditions governing their usage are set forth.

The salient features include the necessity for adequate terminals, off-track versus on-track railroad depots, the volume of tonnage, tractor and semi-trailer operation and methods of procedure and control, weight and protection of loads, haulage distance, economy, and a specific statement of the principal advantages gained through the use of automotive equipment of the type described.

ALTHOUGH I am not an engineer and possess no technical knowledge of the construction of a motor truck, it has been my observation that the motor truck of today is a dependable machine that, for practical purposes, is perfect mechanically; and that the limit of its use as a medium of transportation will depend upon its intelligent application to business and the proper application of business to the vehicle. It is my opinion, therefore, that if the motor truck in any branch of what may be termed "commercial service" is not working as an economic and efficient unit to its theoretical capacity, it is because it does not fit by its construction the conditions under which it must be operated or, if it does fit the conditions, its operation is not systematized so as to get from it the full measure of efficiency that it is capable of giving. Motor-vehicle equipment, as operated today in commercial hauling, is a sort of hit-or-miss proposition; that is, many of those who adopt it for use in their business fail to make a study of the conditions under which it must be operated, or to supervise its operation so as to obtain the maximum results.

My experience in automotive transportation has been in intra-city hauling and the transportation of merchandise between railroad terminals. In that service we use a unit that, by its construction, fits our business, and we have systematized its operations so that we are getting from it the full measure of economy and efficiency. In addition, it has enabled us to perfect a system of terminals in St. Louis that supply a vital transportation need for both the railroads that serve the city and the business community there.

Adequate Terminals Necessary

One of the most important problems that confronts the rail-transportation interests of the Country today is that of adequate terminal facilities in large cities and, in its solution, two factors must be considered; (*a*), the intra-terminal transportation of merchandise interchange between railroads, and (*b*), the intra-city transportation of merchandise between railroad terminals and the store or plant of consignee or consignor. In these factors service and cost are of vital importance to both the railroads and their patrons.

It is a recognized fact that the capacity of our railroads is fixed by that of their terminals. It is obvious, therefore, that such facilities as tend to relieve the rail terminals of business that can be handled otherwise correspondingly increase the capacity of the rail terminals to handle the volume of freight that, on account of its character, must move through such channels and, perforce, increase the capacity of our railroads as a whole.

In St. Louis this is now being done by the company I represent. Using semi-trailer automotive-transportation, it relieves the rail terminals of virtually all of the less-than-carload freight that is interchanged between the Western trunk lines terminating in St. Louis and the Eastern railroads having depots in East St. Louis, Ill., across the Mississippi River, as well as the major portion of the less-than-carload merchandise shipped from and destined to St. Louis proper. Thus, in the correlation of rail and automotive transportation for the handling of both interchange and St. Louis merchandise it has been made possible to handle carload and less-than-carload business more expeditiously in St. Louis than at any other terminal center in the Country.

For the handling of the less-than-carload merchandise of a city, adequate freight facilities mean terminal facilities sufficient to handle such traffic promptly, with freight depots located so as to be accessible at a minimum drayage haul to the greatest number of shippers and receivers of less-than-carload freight. In St. Louis such facilities are furnished by our company in the operation of universal off-track depots conveniently located, to which merchandise shipments for any one or for all of the 24 railroads serving that city, including the Illinois Traction Co. and the Federal Barge Line, may be delivered to or from which incoming freight from any or all roads may be obtained, thereby reducing the cartage or haulage expense to shippers and receivers of freight.

Off-Track Versus On-Track Railroad-Depots

These universal off-track stations serve the railroads and the business community better than would on-track railroad-depots by virtue of the following facts: A universal freight depot on-track for the receipt and delivery of less-than-carload merchandise for all St. Louis railroads would, by its perforced location, entail an increase in drayage expense to shippers and receivers of freight. Moreover, such a universal freight depot of sufficient capacity to handle the less-than-carload merchandise of all St. Louis railroads and permit the loading thereof in box cars, so as to insure through service with a minimum transfer of shipments from car to car en route, would require, if located at a point convenient to the greatest

[1] Vice-president, Columbia Terminals Co., St. Louis.

number of shippers and receivers, a space of such size that the cost of its acquisition would be prohibitive. One universal freight depot on-track of less than that capacity, or several such stations on-track, would not represent adequate facilities; for, in the interest of service and the conservation of box-car equipment, the transfer or consolidation of shipments at other stations would be necessary. In addition, such handling, owing to the light loading of this class of freight, would take a large quantity of equipment from other service for which it might at the time be needed urgently, to say nothing of the additional tax that would be placed on the rail terminal-facilities in the handling of these cars. The location of individual freight depots in St. Louis by each railroad for the handling of less-than-carload merchandise would not insure better service to shipments, and it would increase the cartage expense of shippers and receivers of freight, unless they should have straight loads to and from each depot, which, with most of them, would be very infrequent.

A shipper's truck loaded by 1:00 p. m. could scarcely deliver freight to 12 or more different railroad depots between that hour and 5:00 p. m.; whereas, if delivery were made by 2:00 p. m., which could be done to the most conveniently located of our universal off-track depots, we would make delivery of the shipments to the 12 or more railroads in time for forwarding the same day. This applies likewise to inbound shipments, those that may have been shipped from a dozen different points over as many different railroads, being available for hauling from the universal off-track inbound-depot that the consignee may elect as the facility at which he desires to accept receipt of his shipments.

In St. Louis our company now has eight universal off-track depots; five for the handling of outbound and three for the handling of inbound freight, from and to which less-than-carload St. Louis rates apply, no extra charge being made to shipper or consignee for the movement or handling of freight by our company, the charge for our service being absorbed by the railroads out of their published tariff rates to and from St. Louis. Our facilities thus become in every respect those of the railroads; and, operating as agents for all railroads terminating in St. Louis and East St. Louis, Ill., in the transfer of both inbound and outbound freight between our eight universal off-track depots located on the west side of the Mississippi River and the various railroad freight depots located in St. Louis and East St. Louis, Ill., we have developed a system of automotive transportation that, for practical purposes, places our universal depots "on-track," so to speak, by what amounts virtually to the operation of non-track railroad transportation through the congested industrial sections of St. Louis.

Tremendous Volume of Tonnage Handled

Under this system we handle nearly 7,000,000 lb. of merchandise daily, representing 466 carloads per day, loaded to 15,000 lb. each, or approximately 145,000 carloads per year, and that number of box cars is thereby released for other service. This enormous tonnage, of which 65 per cent comprises that shipped from and destined to St. Louis proper and the remainder that for points beyond St. Louis, interchanged between the railroads terminating in St. Louis and East St. Louis, Ill., is handled more expeditiously and at a lower cost to the railroads, all factors considered, than they could handle it through their rail terminals; and, in addition, on that shipped from and destined to St. Louis, the expense of drayage to shippers and receivers is reduced to a minimum by the convenient location of the universal off-track depots we provide for its handling.

Confronted by the barrier of the Mississippi River, the rail connections of the Eastern lines were built to East St. Louis, Ill., and those of the Western lines to St. Louis, there being no rail connections between these points until the opening of the Eads Bridge for traffic in the summer of 1874. For such rail carriage, the rates on merchandise from and to St. Louis were on a plus basis of 2 cents per 100 lb. more than the East St. Louis, Ill., rates. However, for the more expeditious movement of their business, the majority of St. Louis shippers and receivers teamed or had their consignments teamed between St. Louis and East St. Louis, Ill., which was an added expense.

In 1908, when the St. Louis and East St. Louis, Ill., less-than-carload rates were made the same, the then existing union rail facilities in St. Louis were not adequate to handle the traffic for actual delivery within St. Louis and, as the Eastern railroads terminating in East St. Louis, Ill., could not secure, had they so desired, space in the industrial districts of St. Louis for the erection of their own depots, they entered into an agreement with our company, and another transfer company that was subsequently absorbed by our company, to handle the business. Notwithstanding the fact that they had their own depots in St. Louis, the utility of this arrangement was recognized quickly by the Western roads and they entered into a like agreement for the handling of their business. This had the effect of making us the authorized agent for all the railroads serving St. Louis.

Automotive-Transportation Development

During each succeeding year of operation our hauling methods have undergone a process of studied development. It began with us, of course, with teams, and was changed subsequently in part to motor trucks, but within more recent years we have adopted a form of tractor and semi-trailer automotive-transportation that marks a revolutionary development in the handling of less-than-carload freight within the large industrial city and terminal center of St. Louis.

We found the motor truck to be an improvement over teams in the saving of time, but it did not prove an economical method, due chiefly to the enforced loss of time during the loading and unloading operations. While the speed of the motor truck was considered absolutely essential to meet the growing requirements of our business, it was considered equally essential to find some method that would enable us to use automotive-transportation on an economical basis. Thought was turned to the semi-trailer idea, just as in river transportation the thought in recent years has been along the line of towboats and barge service in order that the heavy investment in steamboat machinery might not be idle during the long time taken for loading and unloading. The cost of operating a railroad for freight purposes, for instance, would be prohibitive were it found necessary to tie up in idleness a locomotive every time a box car was loaded or unloaded.

A search of the market failed to disclose a semi-trailer entirely practicable for the purpose of our operation. There were various types of tractor and semi-trailer successful enough when the operation was limited to pulling, but wholly impractical in operations requiring accurate backing-up, frequently under difficult conditions, such as constantly confront the receipt and delivery of freight at the platform of a railroad freight depot. The difficulty with the semi-trailers to be had was the ab-

sence of any method of controlling the steering of the semi-trailer in reverse operation. Therefore, steps were taken to design a semi-trailer that would overcome this disadvantage.

Four years ago it was found that, with a few minor changes, a certain semi-trailer could be constructed so as to meet our requirements fully. We began, as an experiment, with one tractor and three semi-trailers and the trial proved so successful, practical and economical that 4 additional tractors and 12 additional semi-trailers were ordered immediately. Upon further experiment, we determined upon a policy of displacing our teams and truck equipment with tractor and semi-trailer equipment as rapidly as circumstances would permit. At that time we had in service 600 horses, 350 stake wagons and 72 motor trucks with a capacity of 5 tons each. As against 5 tractors and 15 semi-trailers in use 2 years ago, we now have in operation 56 tractors and 168 semi-trailers, with some of the teams and motor-truck equipment yet to be displaced, as 200 wagons and 55 motor trucks are still being

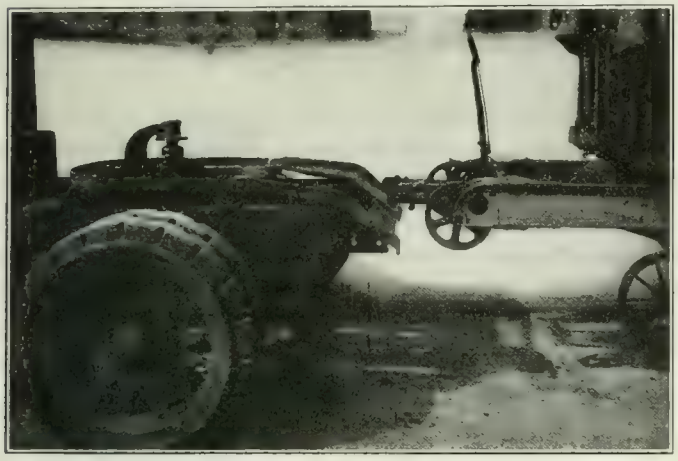

Fig. 1—Coupling Device Employed To Connect the Tractor and the Semi-Trailer

operated and 17 of the 72 motor trucks operated 2 years ago have been converted into tractors at our own shops.

Tractor and Semi-Trailer Operation

Not being an engineer, I am unable to give a technical description of the semi-trailers we used, but I shall endeavor to describe briefly how they work and point out their utility and adaptability in the transportation of merchandise. For efficient operation they should be loaded dead; that is, the tractor during the loading and unloading of semi-trailers should be engaged in the hauling of other semi-trailers under load. Each semi-trailer stands as a unit on four wheels while being loaded and unloaded and, when ready to move, the coupling of tractor and semi-trailer is done instantaneously and automatically, being controlled by the chauffeur while in his seat in the cab. The same operation automatically releases the brakes and elevates the front-end supporting-wheels of the semi-trailer, the load in motion thus being on six wheels, the four wheels of the tractor and the two rear wheels of the semi-trailer. These semi-trailers are equipped with internal expanding drum-brakes that automatically control them while in process of coupling or uncoupling with the tractor, as well as preventing them from over-running the tractor when descending a grade or making a stop on the level. The coupling of tractors and semi-trailers is illustrated in Figs. 1 to 3, showing the equipment in our service. Fig. 1 shows the coupling

Fig. 2—A Tractor and a Semi-Trailer About To Be Coupled

device of a tractor and a semi-trailer; Fig. 2 illustrates a tractor and a semi-trailer about to be coupled; and Fig. 3 is a view of the tractor and the semi-trailer when coupled.

During the operation, the tractor chauffeur remains in his seat; the coupling is done automatically. The tractor, backing-up, lifts the front end of the trailer by engaging the guide wheel with the mounting tracks, then locks the trailer to the fifth-wheel coupling-device on the tractor chassis. The same operation automatically releases the brake and elevates the supporting wheels of the trailer. The whole operation can be reversed by pulling a lever in the chauffeur's cab.

Experience has proved to us the advantages of the semi-trailer over motor trucks operated under similar conditions. Our records show that the average daily mileage of our 5-ton motor-truck was not over 20 miles and, moving at 10 m.p.h., which is about the limit of speed that can be maintained on frequented city streets, they were in actual productive service only 2 hr. daily, the other 6 hr. of a business day being consumed in their loading and unloading operations. By operating on one tractor to three semi-trailers, one semi-trailer is being loaded, one is being unloaded and one is in transit, except that we unload semi-trailers alive at the outbound railroad-depots to check the delivery of each shipment and get a proper receipt thereon. The idleness of the tractor, which represents the considerably heavier portion of the investment, has been reduced by us to a minimum.

Off-Track Station Construction

When we decided to standardize on semi-trailers, we proceeded as rapidly as possible to fit that class of equipment to our business and our business to that equipment.

Fig. 3—The Tractor and the Semi-Trailer Coupled Together and the Auxiliary Front Axle and Pair of Wheels of the Latter Raised

Our facilities were originally built for the handling of business by teams, and it was necessary to make alterations in some of them so as to afford the full measure of economy in the use of semi-trailer equipment. As new facilities are built, the best points obtainable from a thorough survey of modern freight terminals are being incorporated in their construction, together with improvements suggested by our experience in the operation of tractor and semi-trailer equipment.

To give an idea of the plan of construction of new facilities, the Sixth street inbound-depot building is 30 ft. back from the building line on Sixth Street and 15 ft. from a public alley on the west, permitting the dropping of trailers on either side and of their being unloaded there dead without interference to pedestrians or vehicular traffic. Loaded semi-trailers are dropped, those containing mixed shipments being unloaded on the platform for delivery to the various consignees. Straight loads and large lots for one consignee are left on semi-trailers and delivery is made therefrom to the vehicle of consignee.

Fig. 4 illustrates the 11th Street outbound depot and semi-trailers in process of loading. This depot is constructed with a view toward affording across-platform movement of freight; that is, the handling of consignments from the shipper's vehicle across the depot platform to semi-trailers. Frequently, shipper's vehicles pull alongside of semi-trailers and the transfer of shipments is made direct from one vehicle to the other. An outstanding feature of this depot is its immense paved driveway, 60 ft. in width and extending through the entire block length of the structure. This driveway is intersected at the middle by a 40-ft. paved-driveway between the two units of the building, making available for the use of shippers, in the delivery of their outbound freight, four immense platforms having an aggregate length of 740 ft. and being 30 ft. wide, a width determined upon as contributing best to the expeditious handling of freight.

This depot is operated on the four-dump plan, each one of the platforms being set aside for the receipt of freight for a specified group of railroads. Thus, while the depot is universal and receives freight for all railroads, this plan of operation permits the greatest possible dispatch in handling outbound freight, reducing to a minimum the time required for the passage of freight through the depot to our equipment, and thence to the railroad that is to transport it to its final destination. Shipper's vehicles make delivery to the platforms on the inside of this depot, and shipments are trucked across the platform to waiting semi-trailers that are loaded simultaneously. Semi-trailers loaded at this depot are usually straight loads for one railroad; that is, while the load may consist of anywhere from 1 to 100 shipments, from perhaps as many shippers, they are all for movement over the same railroad. At our smaller off-track outbound depots, it is not always possible to confine the loading of each semi-trailer to consignments routed by way of one railroad without holding shipments until a capacity load is accumulated. This would impair the service to our patrons by delaying the delivery of shipments to the railroad and, in these circumstances, shipments for two or more railroads are loaded on a semi-trailer. When it is necessary for us to load shipments for two or more roads on a semi-trailer, it is reflected in an increase in our hauling cost per ton.

Handling Semi-Trailers at Railroad Depots

At outbound railroad-depots, semi-trailers are unloaded alive to check the delivery of each shipment and get a proper receipt thereon. At inbound railroad-depots a supply of semi-trailers sufficient for their requirements is placed daily at the platforms of most of the depots in East St. Louis, Ill., our representative giving a receipt to the railroad for each shipment as it is loaded and, as each loaded semi-trailer is pulled from the depot platform during the day, an empty one is immediately dropped in its place, thus making our semi-trailer equipment always available for loading. We are extending this service to the other railroads as fast as new semi-trailer equipment is received.

This ever-ready supply of our semi-trailers is particularly advantageous to the railroads, as the trailers practically increase the depot platform area and, because of their availability, this permits the transfer of merchandise shipments direct from freight cars thereto, thus effecting a material reduction in the railroad labor cost of handling per ton. In this respect our semi-trailer has a distinct advantage over removable truck bodies, in that they occupy driveway space adjacent to the depot platform; whereas, removable truck bodies occasion an excessive demand upon platform space which is the most valuable and the most urgently needed space about a freight depot.

Tractor and Semi-Trailer Movement-Control

When a semi-trailer is loaded at one of our universal outbound depots, it is picked-up by a tractor and moved to the on-track outbound-depot of the railroad and, after it has been unloaded there by the chauffeur and his helper, it is then placed at the inbound-depot platform of the railroad for reloading and the tractor proceeds to pick up another loaded semi-trailer. The distribution of tractors for the hauling of loaded semi-trailers, and the placing of additional light semi-trailers for loading during the day at depots where they may be needed at the time, is controlled from our general office through an efficient dispatching system. We have a dispatcher in East St. Louis, Ill., and a chief dispatcher in St. Louis; each semi-trailer is reported to them as soon as loading is completed.

As each tractor chauffeur leaves a depot with the first loaded semi-trailer in the morning, the depot so reports to the dispatcher in St. Louis or East St. Louis, Ill., according to the location of the depot from which the start is made, giving the name of the chauffeur, the tractor number and the depot to which the load is destined. This information is immediately exchanged between the dispatchers, whereupon the chief dispatcher makes up a daily operating card for each tractor chauffeur, upon which is recorded his operations currently throughout the day; information thereon being telephoned over a private wire to the dispatchers by the depots. These daily operating cards are kept by the chief dispatcher according to the district to which tractor chauffeurs have loads, so that he may know at all times each and every tractor that is en route to each depot in each district. The location of every tractor and semi-trailer being thus at all times definitely known to the chief dispatcher, when a semi-trailer is loaded and ready to be moved, or when an empty semi-trailer is needed at any particular depot, he can place his hand on the tractor, so to speak, and assign it to the required service without delay.

Weight and Protection of Loads

The average loading of our semi-trailers is 12,000 lb. which, on outbound loads, consist on an average of consignments from 20 different shippers and, on inbound loads, shipments for 25 different consignees. In the con-

solidation thereof on our 9-ton-capacity semi-trailers, congestion at on-track depots is avoided by the reduced number of vehicles they have to serve at their platform doors. Street traffic is also reduced by the displacement of individual conveyances of small capacity in the haul between the shipper and the railroad. We use on our semi-trailer equipment a stake wagon-body 8 ft. x 16 ft. with a waterproof canvas cover, known as a "house top," which is spread in bad weather for the protection of shipments. Fig. 5 shows a loaded semi-trailer with the "house top" spread.

We have found that this cover, when properly adjusted, affords ample protection to the load under all weather conditions, the instances of damage to shipments by bad weather being negligible. In fact, damage to shipments from all causes, those sustained in our depot handling as well as while in transit on our vehicles, for a period of 3 years was, on outbound traffic, but 0.0027 per cent and, on inbound business, 0.0031 per cent of the revenue earned. As compared with a closed body, the stake body affords more elasticity and density of loading as well as avoids the stifling heat of which labor complains in the loading of closed bodies during the summer months.

Distance of Haul and Economy of Operation

The distance of haul between our universal off-track depots and the on-track depots of the railroads on St. Louis merchandise, and between the on-track depots of the railroads on interchanged shipments destined to points beyond St. Louis, is from 1 to 3 miles; between these facilities, an average of from 60 to 75 of our vehicles under load are in transit every hour throughout the day.

By the use of tractor and semi-trailer equipment, we have accomplished the greatest aim in efficient hauling; that is, a reduction in the hauling cost per ton. As compared with motor trucks in similar service, by the use of tractor semi-trailer equipment the cost per ton on our hauling operations has been reduced 50 per cent.

The principal advantages in the use of tractor semi-trailer equipment that have contributed thereto can be summed up briefly as follows:

(1) A larger quantity of freight is transported on each load, as a 3-ton tractor can pull a 9-ton loaded semi-trailer

(2) One tractor serves for three carrying units, each one of treble the ordinary capacity

(3) Constant production by the major part of the investment represented in the tractor because of its not standing idle during the process of loading and unloading

(4) Waiting semi-trailers, enabling uninterrupted and diversified loading

(5) Saving of valuable depot-platform space because of the ever present loading facilities provided by the semi-trailers

(6) Decrease in insurance due to the absence of fire hazards, as semi-trailers loaded with merchandise are parked overnight in buildings containing other merchandise, with no increase in insurance on building or contents. This is not possible with motor trucks, as the presence of fuel therein creates a fire risk that most insurance companies will not underwrite

(7) Decrease in garage space, it being necessary to keep in a garage only the tractors, the average overall length of which is 12 ft. each; empty semi-trailers do not require housing.

(8) An avoidance of idle time for a chauffeur, because a loaded semi-trailer is ready when he reports in the morning. He couples his tractor thereto and proceeds with the load; in like manner he is continuously engaged throughout the day

Fig. 4 One of the Outbound Freight Depots and a Number of Semi-Trailers Being Loaded

Selling Transportation

Tractors and semi-trailers are now used in the transportation of intra-terminal merchandise at several cities other than St. Louis, but their possibilities in that service, as well as their use as a means of effecting economies in the performance of other service that the railroads are now rendering, are not realized fully by those most interested, the builders and operators of automotive equipment. This applies also to the extension of the use of automotive equipment in commercial hauling.

Producers and operators of automotive equipment will come to realize the possibilities of automotive transportation when they sell transportation that fits the requirements of the service in which it is to be used and that opens a field for "transportation engineers," men who, through experience, are competent to analyze each hauling problem as it is presented.

The character of the commodity to be transported, the loading and unloading facilities, the size and weight of loads, the distance of haul, the number of points of delivery and the highway conditions, are a few of the primary factors that the transportation engineer must study and analyze before deciding on the automotive hauling unit best fitted for a particular service.

The motor truck of today has its place in transportation from which it cannot be displaced but, due to its construction, it has its limitations as an economic hauling unit. Automotive equipment involves investment maintenance, depreciation, chauffeur's wages, garage rent and

Fig. 5—A Loaded Semi-Trailer with the "House Top" Spread

various other overhead expenses. All of these items represent a loss in proportion to the idleness of the investment, the major part of which is in the engine; it follows, therefore, that in proportion to the reduction of the idleness of the engine there is an increase in the efficiency, with a decrease in the hauling cost per ton. The engine being an integral part of a motor truck, it is impossible to eliminate its idleness; whereas, with semi-trailers, it is possible to do away with engine idleness during loading and unloading and this should result in a decrease in the hauling cost per ton. Moreover, two-thirds of the hauling power of an engine is wasted when it is used as a carrying unit, as in the case of a motor truck. On the other hand, semi-trailers afford a means of overcoming lost time and lost capacity, with a corresponding reduction in the investment, as one tractor and three semi-trailers represent only one-half the investment in three motor trucks.

The field for the more extensive use of automotive transportation has many possibilities, some of which I know are now being given close study. The more important benefits are summarized as follows:

(1) In the correlation of railroad and automotive transportation is afforded the solution of adequate terminals in large cities as has been demonstrated in St. Louis

(2) Less-than-carload traffic interchanged between railroads at terminal centers can be handled more economically by automotive transportation than by rail carriage

(3) Universal off-track depots, which can be constructed in industrial districts within large cities at locations that would be inaccessible if not prohibitive by the cost of the right-of-way to reach them by rails, serve the railroads and the business community better than would on-track depots

(4) In the correlation of railroad and automotive transportation, the use of tractor semi-trailer equipment improves the service and reduces the hauling cost per ton

(5) The extension of automotive transportation as an efficient hauling medium, in conjunction with the railroads and in commercial service, depends upon how well the equipment is fitted to accomplish the service for which it is to be used

RECORD PRODUCTION OF PORTLAND CEMENT

ONE of the most impressive features of the year 1922 in an economic sense was the unparalleled activity of the cement industry in the United States with its record-breaking figures for the year's production and consumption of Portland cement. These phenomena were, of course, entirely in harmony with the exceptional scale of building operations and of road-building and other construction work in the Country during the past 12 months; but none the less it is a very striking fact that the cement industry alone among the major industries of the United States should have experienced in 1922 far and away the best year in its history. According to the statistics of the production, shipments and stocks of Portland cement that are compiled monthly by the United States Geological Survey, under the direction of G. F. Loughlin, the total production in 1922 was 113,870,000 bbl., as compared with 98,293,000 bbl. produced in 1921, an increase for 1922 over 1921 of 15,577,000 bbl., or 15.8 per cent. Up to 1922, the record year for Portland cement production in the United States was 1920, with a total output of 100,023,245 bbl.; but this output was exceeded in 1922 by approximately 13,847,000 bbl., or 13.8 per cent.

Perhaps even more remarkable than the 1922 production of Portland cement were the year's shipments from the manufacturing establishments, such shipments, of course, roughly measuring the year's consumption. The 1922 shipments totaled 116,563,000 bbl., as compared with 95,051,000 bbl. shipped in 1921, the gain in shipments in 1922 compared with 1921 being 21,512,000 bbl., or 22.6 per cent. It further appears from the figures that the shipments of Portland cement in 1922 exceeded the year's unprecedented production by 2,693,000 bbl., with the result that the stocks at manufacturing establishments at the end of the year were smaller by this amount, equivalent to 23 per cent, than they were at the end of 1921.—*Economic World.*

THE PRODUCTION ENGINEER

MANUFACTURING conditions have changed greatly in the last decade, and during this period labor costs have increased considerably. It, therefore, is more necessary than was the case in the past for every effort to be made to place production on a scientific basis and to raise the status of those persons who are directly responsible for manufacture.

There is no doubt that the successful executive in industry must be a person of good education. An educated mind, capable of logical thought and with orderly mental processes, is an essential in any position of responsibility. To this must be added a full and thorough knowledge of both engineering design and the principles of efficient production.

Too much importance cannot be attached to the training of apprentices and young engineers generally. Five years' practical experience in the workshops is not a day too long for any youth who desires to master the rudiments of modern engineering production, which tends to become more and more complicated.

A phase of engineering education that appears to be almost entirely neglected is that relating to knowledge of organization and administration. Apart from technical literature, such as periodicals and books by specialists, the younger generation of engineers is offered no tangible means of obtaining an insight into such matters as efficient procedure in the cost office, purchasing department and similar sections of the modern works. Practical experience of these departments is of prime importance, but as a general rule it is extremely difficult for apprentices to get any definite instruction on the matters mentioned above.—*Engineering Production* (London).

The Engineering Aspects of Traffic

By William P. Eno[1]

Washington Section Paper

THE author outlines general and special highway-traffic regulations with regard to their application, stating that the general regulations, which have been codified, should be standardized, and that as many as possible of the special regulations should be made uniform as time elapses. Among the engineering problems mentioned are the cutting-off of street corners on a proper radius, the location of car-tracks, the widening of streets, the relation of the streets to the width of the sidewalks and their capacity to carry a given number of lines of vehicles without wasting space. Other subjects for engineering effort include the design of street intersections for new streets, the location of lights, trees and culverts, and the reformation of streets that were laid out before any thought was given to street-traffic regulations. References are made to more lengthy discussions of the subject.

ALTHOUGH it had been apparent for 10 years or more to the few who were then making a study of traffic regulation that the engineering side of traffic was bound to be of supreme importance in the future, it was not until 1914 that the attention of the general public was attracted to this point through an article entitled The Science of Street Traffic.[2] In referring to the fact that street-traffic regulation had existed for only about 10 years, the article said: "Since then the advantages of regulation have become so apparent that civil engineers are turning their attention to the problem and are making a profession of it."

It is beginning to be realized that the police department or boards of aldermen of the various cities and towns should not be allowed to make their own general highway-traffic regulations, because this practice has resulted in confusion and lack of uniformity, bringing about a much larger number of accidents than would have been the case had the regulations been the same all over the Country.

General highway-traffic regulations are those that are suitable for the largest city, but they contain nothing superfluous for the smallest village, and these are the only regulations that any attempt should be made to standardize. They have been condensed into a code which is now known as the Council of National Defense Code of General Highway-Traffic Regulations. They are short because, if they were not, people would not read them. They are reasonable, else they could not be enforced. The last resort of anything in any free country is public opinion, and, if public opinion does not make a law enforceable, that law becomes a detriment and not an advantage to the Country. The Council of National Defense Code has been compiled by students of traffic regulation, many of whom are engineers of distinction, and any future revisions of the code should be made under the direction of similar minds.

Special regulations also should be worked out by technical men, and as many of these regulations as possible should be made uniform as time goes on. Absolute uniformity is, however, impossible in special regulations; therefore, much of the work must be done through police departments. But here, again, the officer in charge of traffic should be selected for his natural traffic-engineering ability, open-mindedness and willingness to study and experiment in order that he may be able to give the best results to his town.

Engineering Problems

The things that are essentially engineering problems begin, perhaps, with cutting off the corners of the streets on a scientific radius instead of by rule of thumb. The locating of car-tracks needs expert study, as do the widening of the streets, their relation to the width of the sidewalks and their capacity to carry a given number of lines of vehicles without wasting space.

The rotary system holds out all sorts of advantages and is probably the most valuable system that has been devised for the regulation of traffic; it can solve many problems that nothing else can. The laying-out of new streets requires much thought and consideration to decide exactly how their intersections should be designed. The matter of the location of lights, of trees and of culverts is of great importance, but this is not a difficult problem if one keeps in mind the fact that trees, lights and culverts should not be placed so as to interfere with the best location of the crosswalks.

We have also the problem of the streets that were laid-out before any thought was given to street-traffic regulation and have lamps, trees and culverts placed in unfortunate positions. These conditions need careful study and the ability to make the best of a bad bargain. The super-elevation of roadways is now at last scientifically begun, and the cross-sectional slant of the roadway to the curve of the road in relation to speed should be encouraged as tending to reduce wear-and-tear on both the road and the vehicle and to increase safety greatly.

I have mentioned only a few of the more important details, confining myself rather closely to my own branch of the work, the handling of vehicular and pedestrian traffic, and not pretending to be competent to discuss with any degree of assurance many of the other branches of engineering work in relation to the problems in road and vehicle construction that form part of this perhaps most important subject of our generation, highways transport. As we all know, highways transport has now passed the railroads in money investment and within a short time may perhaps double that great sum.

By way of caution, in the selection of engineers for civic traffic structural problems, the many mistakes made in the past by those entrusted with such work must be kept in mind to avoid a repetition of such costly blunders in the future.

In the introduction of the first book on traffic[3], the following was said:

> Unless the height of buildings is regulated by law, or by taxation in proportion to their height, or by a combination of the two methods; unless a complete plan for underground rapid-transit, sewers and pipe galleries be adopted before more obstructive subway work is undertaken, no street-traffic rules or regulations or enforcement of them can possibly provide for the natural increase of surface traffic, either on the

[1] Chairman of the board of directors of the Eno Foundation for Highway-Traffic Regulation, City of Washington.

[2] See *World's Work*, February, 1914, p. 398.

[3] See Street-Traffic Regulation, by William P. Eno.

sidewalks or on the roadways of New York City. What would have cost practically nothing but a little forethought a few years ago, will now require tens and, if continued, hundreds or perhaps thousands of millions of dollars eventually. It is the old story of a "stitch in time saves nine"; it is also a serious reflection on the intelligence of the citizens of New York City that they have not sooner taken sufficient interest in these matters of civic government and, by blotting out corrupt politics and appointing decent men, running their city on business principles, avoided such costly blunders.

Other details as to the engineering aspects of traffic can be found in a book[4] published in 1920. These references are given as time will not permit a more lengthy discussion of this complicated subject.

[4] See the Science of Highway-Traffic Regulation, by William P. Eno; particularly Parts 5 to 9 inclusive.

HIGHWAY AND TRAFFIC RECOMMENDATIONS

SOME of the recommendations made by T. J. Wasser, State Highway Engineer of New Jersey, and president of the American Road Builders' Association, in an address before the Thirteenth American Good Roads Congress, Chicago, Jan. 16, 1923, are of interest to the members. These recommendations were that

The minimum graded-width of all main highways be not less than 30 ft.

This graded-width be kept clear of all encroachments.

All traffic rules be made uniform.

A system of marking one-way streets be adopted, which will be uniform as to the type and the location of the markers.

It is desirable to standardize all directionary and cautionary signs as to their color and marking, and that posting signs other than directionary and cautionary on the right-of-way be made unlawful and subject to a fine for each offense.

The erection of signs on property abutting on the highway at curves, railroad crossings and intersections be discontinued, where such signs would obstruct the view of those using the highway.

It is desirable to standardize the colors to be used for the degree of danger where illuminated signs are used; for instance, red at a railroad crossing or dead ends of highway, green for highway intersections and amber for grades and curves.

A uniform traffic-regulation be adopted for intersecting highways to be in effect in the absence of traffic officers.

A uniform maximum-height, width and length of vehicle be adopted.

A uniform gross-weight of vehicle and load for each class of commercial motor vehicle be established.

All gas-filling stations be located on property abutting on the highways, and not on the right-of-way; and all such stations shall display a visible tag on each pump, which shall be placed there by the State Department of Weights and Measures certifying as to the accuracy of said measuring device.

The parking of vehicles on both sides of a highway opposite each other, where a minimum distance of 20 ft. between the vehicles is not provided, be considered a nuisance and be made punishable by a fine.

The erection of all booths and stands for the sale of goods, as well as the displaying of farm produce in containers, within the right-of-way be prohibited, and also the use of vehicles for retailing wares along the highway where such practice would cause persons to congregate on the paved portion be prohibited.

A uniform penalty for operating a defective motor-vehicle on the highway be provided, it being alleged that tail-lamps frequently fail to function due to the wires having been damaged by abrasion or exposure to splashing water, and broken or improperly adjusted brakes and badly worn tires being mentioned.

Legislation be enacted to provide against motorists running past barricades on roads under construction and destroying unfinished work.

Sidewalks be provided for the use of pedestrians along the highway adjacent to built-up communities.

Pedestrians using the highways in the open country shall walk to the left and that operators of all vehicles drive to the right.

When one-piece shipments that exceed the maximum weight-allowed by law are made, they shall be shipped on specially built vehicles designed to distribute the load in a manner consistent with legal requirements; and only after obtaining permission from an authorized source.

Uniform distinctions be made between maintenance, betterment and reconstruction in order that comparisons may be made.

Motor-vehicle taxation or license-fees be not greater than are required to provide the sum necessary for the maintenance of the highways.

Overloaded trucks operating on the highways be seized and held for a period of not less than 5 days, stored at the owner's risk and expense and the owner fined.

Hauling companies who contract for shipments by the ton, when caught overloading their vehicles, should have their license revoked, in addition to any other penalty.

All operators of motor vehicles be licensed, and prohibited from operating a vehicle for more than 12 consecutive hr., to be followed by an 8-hr. rest.

In addition to any uniform motor-vehicle law previously recommended, all applicants for a driver's license or a renewal thereof be required to submit a physician's certificate bearing a date not more than 1 month earlier than the date of the application. This certificate should be accepted only from designated physicians, and be to the effect that the applicant is in fit mental and physical condition to operate a motor vehicle.

The examination for a driver's license include the testing of ability to read and write English, and that a license be granted only to citizens of the United States, with provisions for tourists from other countries.

The owners of all motor-vehicles must carry liability insurance for each vehicle operated.

All vehicles, both motor and horse-drawn, be equipped with clearance light visible from the front and the rear; this light to be of a shape other than round, located on the extreme left side of the vehicle or load if over width, and showing green in the front and red in the rear.

Stop and Direction Signals for Motor Vehicles

By R. N. Falge[1] and W. M. Johnson[1]

Illustrated with Photographs and Drawings

TRAFFIC congestion, the growing popularity of closed cars and the increasing number of motor vehicles used in winter driving are some of the reasons for the insistent demand for electrically lighted stop-signals, which, being entirely automatic in operation, require no thought or action on the part of the driver. No less than 14 automobile companies are now installing such signal systems as initial equipment on their product, and a number of States have passed laws making the use of some form of mechanical or electrical signal compulsory where arm-signalling is impracticable. The advantages of such legislation as a means of promoting safety to both driver and pedestrian are so apparent that there is little doubt that similar action will be taken by other States where the matter is now under consideration. Unfortunately, however, not all of the many signal equipments placed upon the market have received the careful attention in design and construction necessary to insure consistently satisfactory performance. The field has been a new one; in many cases design has been undertaken without sufficient technical information. It is the purpose of this article to analyze the requirements of a satisfactory signal and to suggest improvements.

Typical Signals

The simplest form of signal and the one in most common use today, is the so-called *Stop* signal illustrated in the upper left corner of Fig. 1. This simply indicates that the driver of the car carrying the signal is applying his brakes and slowing-down. The signal is operated automatically; probably the most common form of control is by the brake pedal. This automatic control relieves the driver of the necessity of extending his arm or of manually operating a signalling device when making a stop, which is often so sudden as to require his entire attention.

For initial installation by the car manufacturer, the *Stop* signal is often combined in one housing with the tail-light as shown in lower left corner. This combination gives a unit of pleasing appearance and at the same time the cost is less than for two separate devices. The two units operate independently of each other. Another arrangement is the combination of a *Stop* signal with a parking lamp in one housing. This is somewhat similar to the combined *Stop* signal and tail-light mentioned above.

A modification of the simple *Stop* signal is one that indicates either *Slow* or *Stop*, and is illustrated at the right hand upper corner. The *Slow* warning is lighted when either the clutch or brake pedal is depressed and the *Stop* replaces the *Slow* when both pedals are depressed. The results obtained with this type of signal depend in large part upon the driver's habits. For example, some drivers in wet weather, apply the brake without releasing the clutch until just before the machine comes to a full stop; the resulting indication is very different from that given by the driver who presses both brake and clutch pedals simultaneously. The result is that both *Slow* and *Stop* must be considered warnings of equal value.

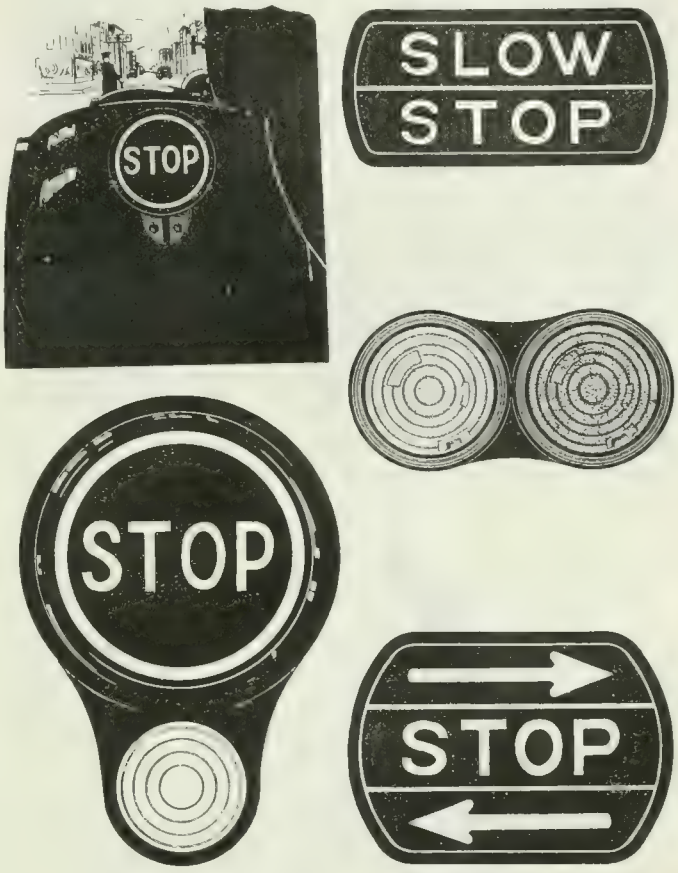

Fig. 1—Typical Stop and Direction Signals

That in the Upper Left Corner Is Perhaps the Most Generally Used Form of Stop Signal and Underneath Is a Combined Stop Signal and Tail-Lamp. The Device in the Upper Right Corner Is a Combination Slow and Stop Signal, While Directly Underneath Is a Two-Color Signal That Indicates Whether the Throttle Is Opened or Closed and at the Lower Right Corner a Signal That Indicates the Direction of a Contemplated Turn as Well as the Application of the Brakes Is Illustrated

Another type of signal, shown at right center, indicates whether the throttle is open or closed. This signal contains two lamps controlled by the accelerator pedal. When the pedal is depressed, a green signal at the rear is lighted, and when it is released the green is turned off and a red signal turned on. A disadvantage of this type of signal is that there is a continual drain on the car battery, for one lamp or the other is lighted all the time the car is in motion. The laws of a few States, moreover, permit only red, yellow or white lights to be carried on motor vehicles.

The *Stop* signal, while of great value, does not in all cases give a complete indication of the driver's intentions. It is desirable that when a turn is contemplated, a signal of the intended direction be given to the driver of the car following. This is readily accomplished by

[1]Engineering department, National Lamp Works of the General Electric Co., Nela Park, Cleveland.

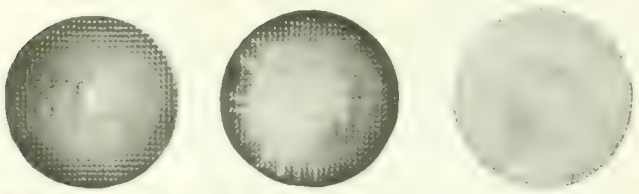

FIG. 2—DIFFUSION OF BRIGHTNESS AND SPARKLE OVER THE LENS SURFACE DEPENDS UPON THE TYPE OF REFLECTOR EMPLOYED

The Inside of the Housing at the Left Is Coated with White Enamel, a Silver-Plated Reflector with an Improper Contour Is Used with the Middle Signal and at the Right a Silver-Plated Parabolic Reflector with the Lamp Properly Placed at the Focus Is Used. A Comparison of the Three Views Indicates That While the Light Is Diffused in the Lamp Filament; in the Middle View the Brightness and the Sparkle Are Uneven and Are Confined to a Portion of the Lens Surface; and at the Right an Even Illumination with a Uniform Sparkle Is Obtained

the combination *Stop* and *Direction* signal, shown in the lower right corner. Arrows, illuminated by lamps within the housing, indicate the direction of the intended turn. These may be combined in one unit, as shown, or may be separated; an arrow is sometimes mounted on each rear fender.

The problem of designing a method of control for a signal that will indicate a contemplated change of direction is much more complicated than for a *Stop* signal alone. Systems of switch control that are actuated by the steering mechanism operate too late to be of any great value to the driver of the car in the rear. It is

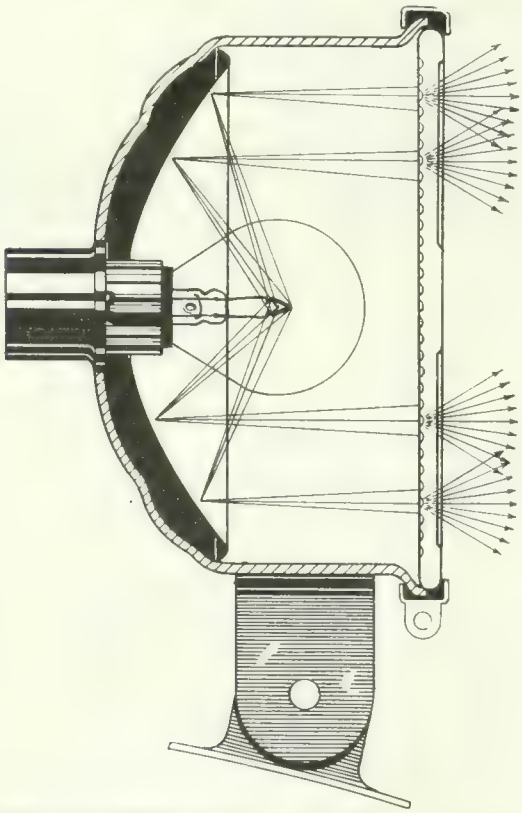

FIG. 3—LIGHT CONTROL IN A STOP SIGNAL OF GOOD OPTICAL DESIGN

desirable that even manually operated switches be turned off by some automatic means, thus relieving the driver of the necessity of attending to this detail. Considerable attention is being given to the problems which a direction signal presents and improvements in the switching devices are constantly being made.

The early types of signal were often the creations of incompetent designers and evidenced inferior workmanship; their only claim to merit was low price. They are being gradually replaced by units which function more effectively and with entire reliability.

The *Stop* signals of today are most often mounted on the left rear fender. For best appearance, the top of the housing is usually placed level with the top of the fender.

IMPORTANCE OF INDICATOR OR TELL-TALE

The driver installs a warning signal in order that his intentions will be made known to traffic without conscious effort on his part. He soon learns that his signal operates effectively and grows accustomed to relying entirely upon it. For this reason, it is of the greatest importance that some means be provided which will inform him unfailingly every time he uses his signal that it is operating properly. This assurance is obtained by a small indicator-lamp, placed on the instrument-board or dash in view of the driver, which flashes or lights every time the signal operates. In recognition of the importance of an indicator, the Connecticut law now requires that a device of this kind be provided with electrically lighted rear signals. In the event of a damage suit arising from a collision, the driver's position is materially strengthened if he is sure that his warning signal was operating properly.

CHARACTERISTICS OF A SATISFACTORY SIGNAL

A signal device to give complete satisfaction should have the following characteristics:

(1) Be sufficiently bright to compel attention in the daytime

(2) Not cause glare at night which is so great as to interfere materially with the vision of the driver of the car behind

(3) The switching device should operate so that the signal indicates the intentions of the driver of a change of speed or direction, or both, before any change has taken place

(4) It should be provided with some form of reliable indicator device to keep the driver informed that it is working

(5) Since the prime function of a signal device is to promote safety, it should be reliable. A minimum of attention should be required to keep it in operating condition

(6) Any parts requiring replacement should be readily available

ESSENTIALS OF SIGNAL-SYSTEM DESIGN

For the signal, the 21-cp. headlight lamp now used on all cars is recommended. The highly concentrated filament is adapted to use with the reflector and lens combination employed in signal devices; its brightness is sufficient for the purpose and this brightness is, moreover, maintained throughout the life of the lamp. Since this lamp is standard for headlights, a spare is usually available in the driver's kit. Although satisfactory signals employing either single or double-contact sockets are manufactured, the single contact is preferred because under the limitations of available space better socket construction is possible, and because the car frame, which acts as the return circuit, has a very low resistance. Moreover, when the single-contact socket is used, the signal lamp and the standard headlight lamp are in general interchangeable.

For the indicator, the 2-cp. lamp of the type used for lighting the instruments is recommended. This lamp provides sufficient light for the purpose, consumes but

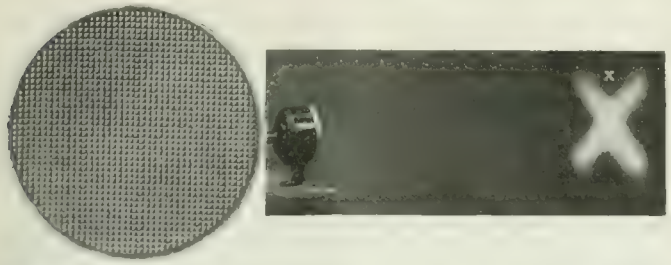

FIG. 4—LENS WITH SMALL PYRAMID-SHAPED PRISMS AND THE CROSS-SECTION OF THE BEAM FROM THIS LENS WHEN THE PROPER LAMP AND REFLECTOR ARE USED

little energy, is interchangeable with other lamps on the car, and is a standard lamp regularly carried in stock. The double-contact socket facilitates proper connection in the circuit.

To provide effective illumination for daytime signalling it is necessary that as much of the light from the lamp as possible be confined within the angle in which it is intended that the signal attract attention. It is essential that an efficient reflector be provided behind the lamp not only to redirect and thereby utilize the light rays from the lamp that are not initially directed toward the cover glass, but also, as will be observed from a comparison of the three views in Fig. 2, to provide a uniform sparkle over the entire lens face. White enamel on the inside of the housing acts as an efficient reflector, but light rays striking it are diffused, giving the lens a lifeless appearance except for the sparkle over a small area in line with the lamp filament. The appearance as well

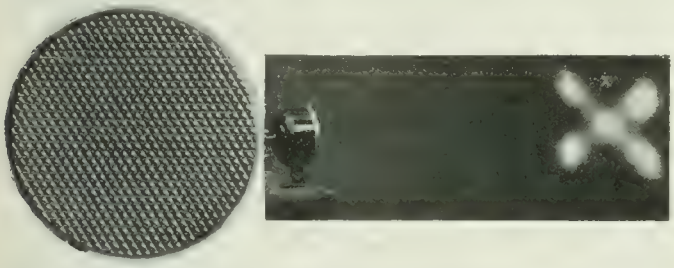

FIG. 5—LENS WITH SMALL DIAMOND-SHAPED PRISMS AND THE CROSS-SECTION OF THE BEAM FROM THIS LENS WHEN THE PROPER LAMP AND REFLECTOR ARE USED

as the effectiveness of the signal may be improved through the use of a reflector with a highly polished surface so designed as to make it possible to reflect images of the filament but slightly less brilliant than the filament itself to every portion of the lens face; by proper lens design, sparkle over the entire face of the lens is obtained. The method most commonly employed and a very effective one, is that illustrated in Fig. 3, in which a highly polished parabolic reflector is used to redirect the rays from the filament in such a manner as to cover the entire lens surface; the lens, in turn, redirects the rays so that a bright spot is visible from each small irregularity from any point within the angle required. The surface of the reflector should have a high reflection-factor and be capable of retaining a high polish. In Table 1 are given the reflection factors of various polished metals suitable for use as reflectors.

TABLE 1—REFLECTION FACTORS OF VARIOUS METALS

Surface	Reflection Factor, Per Cent
Silver-plated	85 to 90
Aluminum	62 to 67
Nickel-plated	50 to 55

Red, bordering on orange, has been used almost universally for *Stop* signal lenses. For *Direction* and other signals, green and yellow as well as red have been used. Natural colored glass assures a permanent color. Dips, sprays, etc., sometimes have a tendency to flake or peel off under service conditions.

In order that the signal may have brightness and sparkle, the lens surface should be composed of many small prisms or individual lenses capable of breaking up the solid beam of light from the reflector into a multitude of overlapping individual beams traveling in the same general direction. These irregularities should preferably be on the inner side to facilitate keeping the outer surface clean. The four-sided prisms of commercial glassware bend the rays of light in four different directions, producing two bands of light that cross at an angle

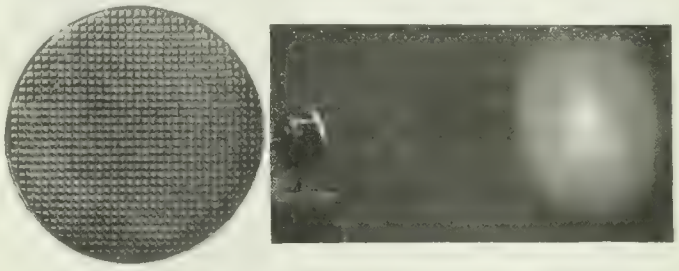

FIG. 6—LENS WITH A DESIGN CONSISTING OF SMALL BULLSEYES OR BUTTONS, EITHER RAISED OR INDENTED, AND THE CROSS-SECTION OF THE BEAM FROM THIS LENS WHEN THE PROPER LAMP AND REFLECTOR ARE USED

depending upon the angle of the prisms. There is a definite "dark spot" in the beam from prisms of this description. Should the driver approaching from the rear of the car with such a signal happen to be in the dark area, as at *x*, Figs. 4 and 5, the effectiveness of the signal is greatly reduced. The design of individual prisms or lenses is highly important. Each should throw a part of the light which strikes it to every part of the main beam from the entire lens. The photographs of Figs. 4 and 5 illustrate the limitations of four-sided prismatic designs and the better results obtainable through the use of small bullseyes or buttons are brought out in Fig. 6. The cross-section of the beam from this type of lens shows no dark areas. Consequently the driver in the rear receives a uniform flash at any point in the beam. This type of prism design is most effective. A spread of light of about 40 deg. from each small bullseye gives satisfactory results. Another possible method is to pebble the surface of the reflector itself; smooth cover glass may be employed and a result somewhat similar to that produced by the bullseye design obtained, although the efficiency is somewhat lower due to cross reflection.

FIG. 7—THREE TYPICAL FACE PATTERNS

At the Left Only the Letters Are Visible and the Remainder of the Lens Face Is Opaque; While the Total Bright Area Is Small and No Annoying Glare Is Produced at Night, a Tendency for the Letters To Blur Exists. In the Central View Only the Letters Are Opaque and the Remainder of the Lens Face Is Visible; the Large Exposed Area in This Case Is Likely To Cause Serious Glare at Night. In the Design at the Right Only the Letters and a Circular Border Are Visible and the Remainder of the Lens Face Is Opaque; This Is a Very Satisfactory Design Since the Addition of the Lighted Border Lessens the Tendency of the Letters To Blur, While the Total Exposed Area Is Kept Sufficiently Small To Avoid Objectionable Glare at Night

The visibility of a signal in daylight depends very largely upon its brightness, and to compel attention in the daytime it is necessary that the brightness be of a high order. This brightness may be prevented from producing a blinding effect at night by keeping the bright area small in size, for glare is a function of both brightness and the quantity of light. For this reason certain portions of the lens are opaqued. Three representative face designs are shown in Fig. 7. As explained in the captions, an illuminated border increases the legibility of illuminated characters on a dark background at night. This feature is of importance in the design of direction signals that depend upon legibility rather than color to indicate the direction of the turn.

The housing should be as nearly dust and waterproof as possible, to reduce tarnishing of the polished surface of the reflector to a minimum. The corrosive action of salt water renders reflectors used in sea-side atmosphere especially susceptible to tarnish. A very slight layer of dust greatly impairs the reflecting qualities of the mirrored surface and reduces the brightness of the signal accordingly. Rubber gaskets should not be used to render the housing moisture-proof since the sulphur content of the rubber soon discolors the mirrored reflector surface. Cork or felt gaskets have proved satisfactory. A small hole or vent at the bottom of the housing is usually provided, as in headlamp design, to prevent collection of moisture.

The indicator usually takes the form of a low-candlepower lamp, mounted on the dash, which lights or flashes when the signal operates. It should be designed and placed so that the driver will be conscious of its flashing even in bright sunlight. Its indication should be positive and definitely dependent upon proper operation of the signal. It should be connected in the circuit so that its operation does not materially reduce the brilliancy of the signal itself and, for reasons already stated, it should be designed for a standard lamp.

In some cases bare lamps have been used, but the glare at night is likely to be objectionable. Where colored, they would be classed as special lamps and are therefore open to the objections previously mentioned. Various designs of glass for indicator-lamp caps have appeared on the market. In some cases the glass has had its surface cut in facets resembling a jewel. A very satisfactory form of cover glass is obtained by using a colored glass with the inner surface designed as recommended for signal lenses. This design provides sufficient angular spread and brightness with a 2-cp. lamp to render the indicator clearly noticeable to the driver in bright sunlight, without causing objectionable glare at night.

The wiring of the indicator must be such that if the signal lamp burns-out, the wire breaks at some point or the switch fails to close or to separate, the indicator lamp will, through its improper operation, call attention to the trouble. Failure of the indicator lamp itself can be checked by operating the signal switch and watching the ammeter; a reading of about 3 amp. as the switch is operated, indicates that the signal lamp is operating properly and that the indicator lamp is burned out.

Four of the most common wiring-plans employed for the indicator system may, for purposes of discussion, be termed the series, the shunt, the series relay and the series flasher. The first method consists of placing the indicator lamp in series with the signal lamps and the former is lighted as long as the signal lamp is on. To obtain brightness at the signal, it is necessary virtually to remove part of the filament from the signal lamp and place it in the bulb of the indicator lamp. This is objectionable because it makes necessary the use of special lamps in both signal and indicator, for a standard 21-cp. lamp used in series with any type of indicator lamp will operate at a materially decreased brightness. The fact that special lamps are required for both signal and indicator means that when either lamp burns out, the user will have great difficulty in obtaining a renewal, since special lamps are not to be found in the stock of the ordinary lamp-dealer.

The shunt system consists of a resistance placed in the signal-lamp circuit around which is shunted a low-voltage indicator-lamp. The voltage-drop across the resistance is sufficient to light the indicator lamp which remains lighted as long as the signal lamp is on. This voltage-drop across the resistance, however, reduces the voltage available at the signal lamp, with the result that its candlepower is considerably reduced. Where standard lamps are employed with this system the candlepower loss at the signal is great even though the indicator lamp is but dimly lighted. This system therefore has very much the same disadvantages as the series method of connection, in that the brilliancy of the signal lamp is seriously reduced by the indicating device. This method has been tried out by several manufacturers of signal devices, and in almost all cases has been discarded.

The series-relay system employs a standard 2-cp. lamp on the dash with the standard 21-cp. lamp in the signal. The dash lamp is lighted by the action of a magnetic relay in the signal-lamp circuit which closes a contact, thus lighting the indicator lamp. The indicator lamp remains lighted as long as the signal lamp burns. When the signal is turned off, the magnet releases its hold, the contact opens, and the indicator lamp goes out. One of the cardinal points to be remembered in connection with the design of a safety device is the necessity of keeping the number of parts in which there is a chance of failure, even though remote, to a minimum; with the series-relay system there is always the possibility of sticking contacts. A reasonably reliable relay is also necessarily expensive. To render the signal effective it is necessary that the resistance of the winding be kept extremely low.

The series flasher appears to be the simplest and most effective method of indicator-lamp control yet devised. A standard 2-cp. lamp is used for the indicator and a standard 21-cp. lamp for the signal. As the switch is operated, the movable member *a* passing to the position *b* momentarily places the two lamps in series. The 2-cp. lamp, having the higher resistance, is lighted to practically its full brilliancy, although the current at this time is insufficient to light the larger signal lamp. As the switch action is completed by the movable member passing to position *c*, the indicator lamp is short-circuited and goes out and full voltage is impressed on the signal lamp, which then lights at full brilliancy. This process is repeated in the reverse order as the switch arm *a* moves back to its original position. A flash of the indicator lamp is thus obtained each time the signal is turned on and off.

With a slight change this indicator system can be readily applied with equal effectiveness to a multiple signal system comprising *Direction* as well as *Stop* signals. Fig. 9 shows the connections for such a system.

Switches should follow certain recognized fundamentals of design regardless of whether they are operated automatically or manually. Many of the difficulties that were experienced with the early forms of electrically lighted signals were due directly to faulty switch design.

Elements of switch design that result in low electrical resistance and more satisfactory operation in general are

(1) Wiping contacts rather than butt contacts
(2) Air insulation between fingers
(3) Reasonably stiff spring fingers of generous size
(4) Short action

The usual instruction booklet accompanying signal equipments recommends that the switch be placed underneath the car; in initial equipment installations, it is commonly mounted on the chassis. Since the switch is likely to be exposed to exhaust fumes, mud, etc., it is essential that an adequate housing be provided.

For satisfactory lamp performance sockets should be well designed both mechanically and electrically. Poor contacts frequently cause a high resistance-drop and a consequent loss in candlepower at the lamp. Furthermore, the heat developed at the points of poor contact may soften an inferior composition to such an extent that it is forced out of the shell by the spring pressure, rendering the socket unserviceable; even summer temperatures are sufficient to produce this softening in the poorer grades of material. Undersized springs and springs which may carry a considerable part of the current are frequent sources of trouble.

Important electrical and mechanical features are

(1) Moisture-proof insulating material which will not soften under moderate heat, fastened securely to the shells
(2) A current path of low and unvarying resistance
(3) Soldered electrical connections, where practicable, free from any bending action or strain at the joint
(4) Sufficient stock, where binding screws are used, to prevent stripping of the threads
(5) Rustproof springs, providing from 50 to 150-oz. pressure on the lamp-base contacts, preferably arranged so that they cannot carry current
(6) Protection from chafing where insulated wire touches the socket shell

Armored cable is accepted as the standard of good practice in automobile wiring, and it is especially desirable in the case of signal systems, where safety and continuity of operation are essentials. The oiled linen insulation of armored cable is practically impervious to gasoline, oil or water, while the metal armor protects the insulation from abrasion. This is especially advantageous in installations made by the car-owner, where the wire is likely to be led through any convenient hole and may be subject to considerable wearing action. The wire should be No. 14 B. & S. gage to insure against loss of candlepower at the signal lamp from excessive resistance in the wire itself.

The signal circuit should never be connected directly to the car battery without fusing. If no fuse is supplied with the signal equipment, care should be taken to connect it to some part of the electrical system of the car that is properly fused. A practice, electrically equivalent to link fuses fastened firmly under binding-posts, is recommended rather than the use of cartridge fuses and clips employing butt contacts. Due to the lack of cleaning action, small area of contact, corrosion, electrochemical action, etc., the cartridge fuse is very often the source of considerable voltage-drop. If cartridge fuses are used, both the fuse ferrules and the clips should be nickel-plated to prevent electrolytic action.

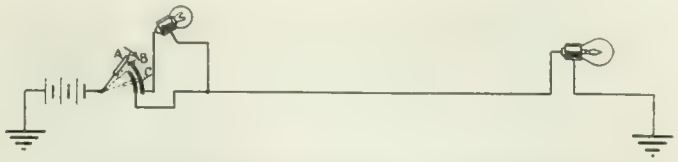

FIG. 8—THE SERIES-FLASHER CONNECTION OF THE SIGNAL AND INDICATOR LIGHT

IMPORTANCE OF A MINIMUM ELECTRICAL RESISTANCE

In the discussion of the electrical design of the various component parts of the signal system, emphasis has been laid upon the importance of keeping the electrical resistance of the circuit at a minimum. The reason for this becomes apparent when one considers that voltage-drop in a circuit is equal to the resistance multiplied by the current and that motor-vehicle lamps are necessarily high-current lamps. The standard 21-cp. 6 to 8 volt lamp, for example, while drawing only 20 watts from the battery, nevertheless uses more *current* than a 115-volt lamp of the 300-watt size and for a proportional candlepower loss would require an even larger size of wire.

The voltage-drop in the circuit, which means less voltage at the lamp filament, has a far more serious effect upon the candlepower of the lamp than is generally realized; a slight reduction in the voltage produces a material reduction in candlepower. For example, a 10-per cent loss in the voltage at the filament results in a 30-per cent loss in the candlepower of the lamp.

Voltage losses due to unnecessarily high resistance may occur in the switches, sockets, fuses or the wiring itself. Attention to the details of electrical design as discussed above will materially reduce these losses and make for greater effectiveness of the system as a whole.

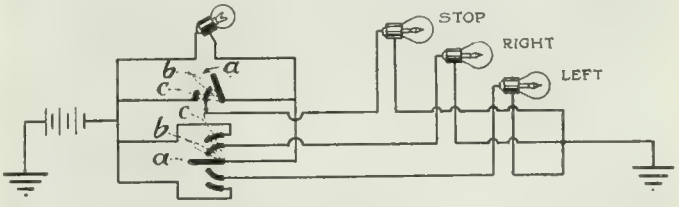

FIG. 9—AN ADAPTATION OF THE SERIES-FLASHER SYSTEM TO SIGNALS USING SEVERAL LAMPS

RECLAMATION OF USED PETROLEUM LUBRICATING OILS

A LARGE amount of lubricating oil is now wasted because it is thrown away as unfit for further use. Yet such oils can be reclaimed and made as good as new, or even better, by simple apparatus already commercially available. For example, the oil in the crankcases of automobiles becomes contaminated with dust and dirt and diluted with the gasoline that leaks into it, and when the owner reads his book of instructions or is otherwise reminded of crankcase dilution, he drains out the oil and throws it away. This is a needless waste and in certain cities arrangements have already been made to collect and reclaim crankcase oil.

In an investigation that the Bureau of Standards has conducted with apparatus for reclaiming oil, it was found that, judging by all the commonly accepted standards, the reclaimed oil is as good as new. Certain changes in the oil could be detected by special tests, but it is a matter for future investigation to decide whether or not these changes are detrimental or whether these special tests are necessary.

Taxicab-Body Construction

By Hugh G. Bersie[1]

Cleveland Automotive Transportation Meeting Paper — *Illustrated with* Diagrams and Photographs

THE author states briefly the phenomenal growth of taxicab usage and consequent demand for this type of motor vehicle, mentions the differences in body requirements for taxicabs as compared with those of passenger cars and describes the methods used to secure durability in taxicab-body construction to discount the severe service to which the body is subjected.

Tabular data are presented and comment made regarding the woods that are suitable for body framework, and the methods of joining frame members, and reinforcing frame joints are outlined. The desirable types of roof and the factors that influence design are discussed at some length, illustrations being presented also, and minor considerations such as types of hardware, dash and instrument-boards, are included. A brief summary states present conditions, and a bibliographical list is appended of informative publications relating to the subject.

ON Jan. 1, 1922, there were 75,000 taxicabs operating in the United States, an increase of 46 per cent as compared with Jan. 1, 1921. It is estimated that on Jan. 1, 1923, at least 110,000 cabs were in service. These figures serve to indicate the rapid progress being made in the field.

The efforts of many passenger-car builders have been directed along the line of producing an inexpensive lightweight closed-car. The taxicab, on the other hand, must be durable and so well built as to run approximately 50,000 miles per year as compared with the passenger-car's average of about 7000 miles. Taxicab service demands not only the maximum durability in the body, the engine

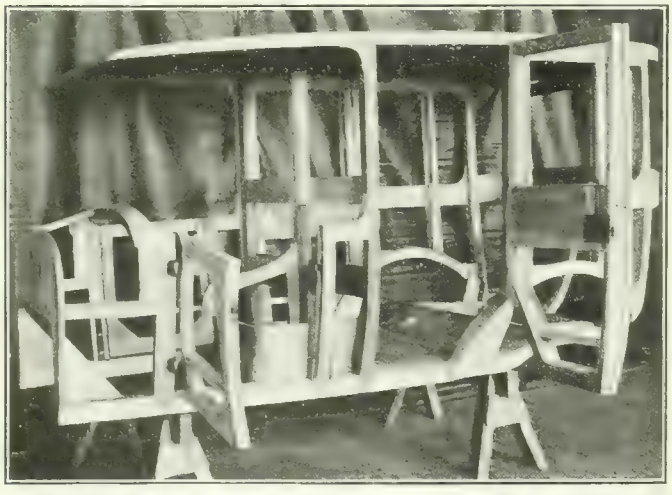

Fig. 1—Taxicab Body Showing Heavy Sills, Door Pillars and Door Frames

and the chassis, but also provision for the satisfactory and easy replacement of any worn or damaged parts, a factor often overlooked. The plan of this paper is to suggest a means of attaining these ends in body construction.

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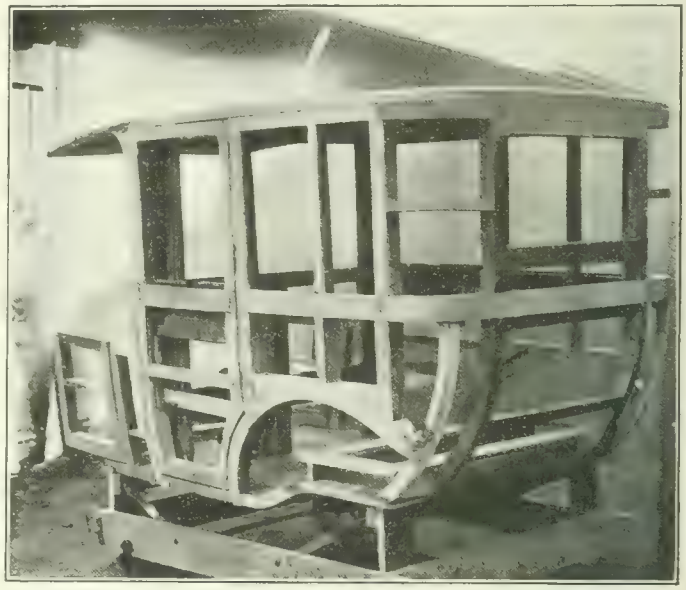

Fig. 2—A Substantial, Well-Built Cab in Which Both Ash and Oak Are Used for Frame Members

Methods of Securing Durability

The prospective purchaser of a taxicab is interested in the durability of the body as well as that of the engine and the chassis. The taxicab's appearance is a business asset to him. Very likely, it influences the amount of his business more than is commonly supposed. Accordingly, taxicab-body design and workmanship are of such importance as to warrant their serious analysis and improvement. We shall begin with the body framework, because the quality of the whole job is reflected in this one item more than in any one other.

First, heavy sills are very desirable. They are about 50 per cent heavier than in passenger-car bodies of the same size. In Fig. 1, the heavy type of sill is noticeable. The numerous "gunstocks," as well as the panelled roof, reinforce the frame members. That part of the sill which is over the wheelhousing can be reinforced by an iron strap applied to the side of the sill. Bent or formed sills are rarely if ever used; it is customary to build-up the sills by screwing and gluing several pieces together to secure the required shape. Tests indicate that the four-piece construction is most desirable.

The door pillars and door frames are next in importance. Since the doors themselves must be exceptionally heavy so as to prevent warping, it follows also that their pillars must be correspondingly heavy. The rear pillars may be about 2 in. thick and should at no point have deep mortises or cut-outs that would weaken them at these places. Such cut-outs weaken the pillars more than a computation of the section moduli would indicate, for

the stresses tend to concentrate at these points. Rear doors, as light as those in passenger cars, will soon warp so that they will not close at the upper front-corners. Front doors have the lock near the upper corner, and hence the lower corner tends to spring away so that it does not close flush. This can be remedied by screwing a diagonal steel strap to the door framework on the inside. This strap pulls the corner in; it subsequently can be covered by the door lining. Fig. 2 illustrates the heavy construction of doors and pillars desirable in taxicab bodies. This body, like the body shown in Fig. 1, carries a full-panelled roof.

Woods Suitable for Body Framework

Mountain or white ash, Fraxinus Americana, is the best wood for frame members. The substitution of yellow poplar has been made to some extent, but its strength and screw-holding properties do not equal that of ash. The value of poplar lies in its use for miscellaneous parts, such as arm rests, that subsequently are upholstered. Upholsterers like to work on poplar, because nails are easily driven into it.

It is often valuable to have information on the strength properties of the various woods that are suitable and available for body construction. Table No. 1 lists the strength values of these woods. Complete information on this subject is available in Government reports on the Mechanical Properties of Woods Grown in the United States.[2]

TABLE 1[a] — STRENGTH PROPERTIES OF WOODS USED IN AUTOMOBILE-BODY BUILDING

Species of Wood	Where Grown	Weight, Air Dried, Lb. per Cu. Ft.	Strength as a Beam or Post	Shock Resisting Ability	Stiffness
White Ash, Forest Grown	Arkansas West Virginia	40	100	100	100
White Ash, Second Growth	New York	44	122	120	118
Sugar Maple	Indiana Pennsylvania Wisconsin	43	104	90	106
White Oak	Arkansas Indiana Louisiana	48	97	96	99
Yellow Poplar	Tennessee	27	67	41	94

[a] Information given in Forest Products Laboratory Report on Project 6516, M-1.

"Case-hardening" of lumber in the kiln-drying will cause the wood to warp when shaped into the frame members. This condition, its cause and the remedy are fully described by the reports of the Forest Products Laboratory.[3] Light-weight ash is often brash and should not be used. A minimum specific gravity of 0.56, based on oven dry-weight and volume, is suggested by the Forest Products Laboratory. Sometimes, ash of good weight is brash, due to the presence of decay. Stains frequently indicate this decay, and lumber containing stains should be regarded with suspicion.

[2] See United States Department of Agriculture Bulletin No. 556.
[3] See Forest Products Laboratory Technical Note No. 112.
[4] See Forest Products Laboratory Technical Note No. 104.

Results of laboratory tests indicate that the different woods vary considerably in their screw-holding properties. The woods in this respect rank as follows: (*a*), sugar maple; (*b*), white ash; (*c*), white oak; and (*d*), yellow poplar. Poplar is very inferior in this respect but, as stated above, it is valuable for trimming strips to which upholstering is subsequently applied.

Methods of Joining Frame Members

The best practice is that of gluing and screwing all joints of the frame members. Long screws are employed and carefully driven immediately after the application of glue to the joint. Animal glue is frequently used because of its convenience. In using this glue, it should be remembered that long-continued heating reduces its strength.[4] Waterproof glues are valuable when care is taken in their proper mixing.

The quality of a job is judged to a great extent by the joints. To secure tight frame-joints, careful workmanship is required. Modern woodworking machines have been highly developed so as to make the forming of the joints almost automatic, but these do not eliminate the need of careful, conscientious workmen for the actual assembly, men who will reject members that have been formed improperly. The racking twisting stresses to which a body is subjected necessitate the best joints; otherwise, body squeaks soon develop, the doors fail to open and close properly, and the body is condemned to the junk heap too soon. Regarding the need of reinforcing frame joints, an inspection of Figs. 1 and 2 shows the large number of "gunstocks," or corner reinforcements, which act structurally as gusset plates, taking some of the strain ordinarily carried by the joints themselves. This sort of construction is neglected in passenger-car bodies, but it is very essential in cabs.

Types of Hardware and Molding

Door hinges and locks have been an object of much study. The rear-door hinges are almost universally of the standard curved-joint pattern of malleable iron. From the standpoint of both durability and easy replacement, they are far better than the concealed type. They have the additional merit of carrying the door back as it swings, and thus increasing the width of the door opening. For safety's sake, rear-door catches are of the two-step variety.

Aluminum molding is used somewhat largely, not only on the body but also for the drip-rail on the roof. This molding can be fastened into place by screws or cement-coated nails. In the latter instance, a good method is that of spinning a conical circular hole in the molding by the use of a revolving center punch. This process forces the metal up, so that the metal subsequently can be hammered down in place after the brad is driven. The method described is one lending itself to fast production, and also one assuring that the finish on the molding will be relatively permanent.

Types of Roof

Taxicab roofs are designed and constructed far differently than for passenger cars. The panel roof is in universal favor with taxicab builders and, when properly constructed and installed, gives excellent service in all closed cars. The trouble that was formerly experienced with drumming or vibration has been practically eliminated by proper methods of installation. At present, all large-quantity cab-builders use plywood molded-roofs.

One method well known to the trade for dampening out roof vibrations consists of fitting felt or padding between

FIG. 3—PLYWOOD CAB ROOF CARRYING SEVEN MEN

the roof-panel and the ribs. However, this has been found only partially effective. Very frequently the drumming experienced in closed cars is not due to the roof, but rather to the glass; such drumming can be detected by placing one's hands on the window glass. In the Yellow Cab body the practice of insulating both the glass from the frame and the frame from the body is followed. Vibration of the roof itself may be eliminated by a certain type of construction that has so far proved wholly effective; it consists in the installation of the roof in two pieces, the joint being over the partition between the driver and the passenger compartments. We suspected

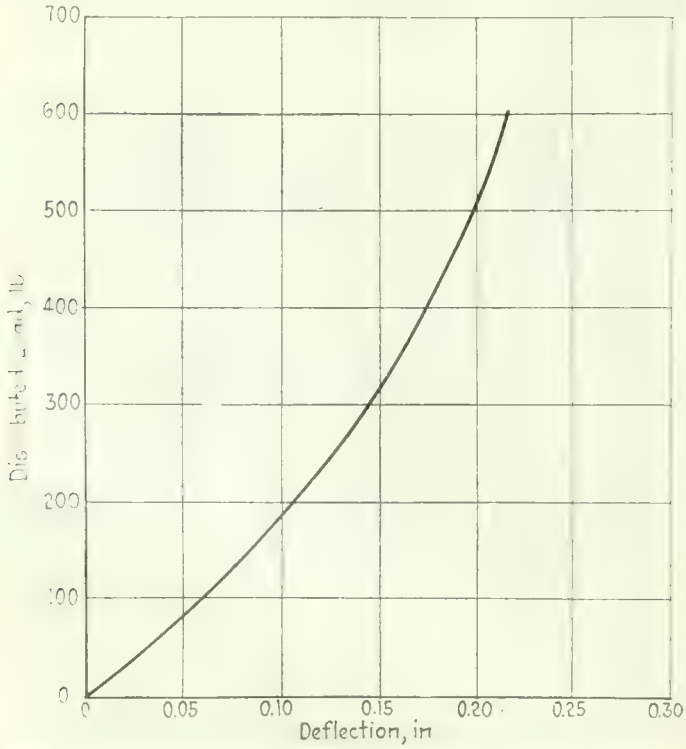

FIG. 4—LOAD-DEFLECTION CURVE OF A UNIFORMLY LOADED PLYWOOD ROOF

that this would eliminate the trouble, several years ago. Recently, complete confirmation has been made by a large-quantity body-builder who tried this method. The theory back of this plan is the isolation of the two portions of the roof, so that any slight vibration is damped-out rather than reinforced. It was feared that the joint would weaken the roof, but service tests have indicated that, if anything, it is stronger. At any rate, these roofs have plenty of longitudinal stiffness to spare. Bending tests made on our 5/16-in. roofs, 59 x 97 in., glued to a frame of ash showed that the panel strengthened this roof by more than 85 per cent. Moreover, the frames used were exceedingly heavy; 2 in. deep and 2¾ in. wide, and had no ribs.

However, operators consider the transverse strength of the plywood roof to be of the greater value. In 90 per cent of the accidents to Yellow Cabs, the blow is delivered to the rear quarter panels below the belt line, right

FIG. 5—HYDRAULIC, STEAM HEATED DIES USED FOR THE FORMING OR MOLDING OF TAXICAB ROOFS

or left side, with the result that in very few cases the destruction extends beyond the rear door pillars, it is most remote when it extends beyond the partition. The Yellow Cab Mfg. Co. says that this is due to the strength of the particular type of roof panel employed as well as to its methods of applying such roofs.

The need of the greater strength afforded by a plywood roof is apparent when the strengths of the average roof-rails and roof-ribs are determined. For instance, a roof-rail of ash of average section 3 in. deep and 1⅞ in wide, will deflect 1 in. under a horizontal side-load of 165 lb. applied at the center of a 90-in. length. Suppose that the load is distributed, say 10 lb. per rib for eight ribs in a 90-in. length, then the frame would be spread ⅝ in. at the middle portion. This shows how deficient the roof-rail and roof-ribs are with respect to lateral or transverse strength, and slats or wire-mesh do not increase its strength very much. The adoption of a canopy plywood roof gives the roof a strength that permits the use of a slat construction and a safety opening to the rear of the center partitions. The enormous strength of the plywood roof is shown in Fig. 3, where a 5/16-in. roof is carrying the weight of seven men, their estimated weight being 1000 lb.

A quantitative test made along similar lines gives the load-deflection curve shown in Fig. 4. In this test, one of our 5/16-in. roofs glued to an ash frame, having a roof-rail 2 in. deep and 2¾-in. wide, with no supporting ribs, carried a uniformly distributed load of 600 lb., with a central deflection of only 0.237 in. A maximum total load of 950 lb. was carried.

Construction of Plywood Roof

The panels are furnished by the manufacturers, molded to the required shape. Fig. 5 illustrates the dies employed for the forming of taxicab roofs. It should be understood that, in this particular process, the panels are first glued-up flat in hydraulic steam-heated presses. Subsequently they are placed in steaming tanks or vats. While wet and somewhat softened, the panels are pressed out to shape in the steam-heated dies. Much research has been directed toward the improvement of this process until, at present, the results are very satisfactory.

Practically all of the roofs are of the three-ply construction, ¼ or 5/16 in. thick. Upon receiving these panels from the manufacturer, the body-builder band-saws them to shape from a template and then clamps and glues the panel to the roof-rail or the frame at all edges. Fig. 6 illustrates this construction, wherein the roof-rail has been rounded or formed on a shaping machine after the glue has set. Ribs are not employed in that portion of the roof over the driver; at that section, this roof gives a smooth panelled appearance without the need of upholstering or interior covering.

Some builders do not consider it necessary or even desirable to attach the passenger portion of the roof to the roof-ribs. In case the panel is nailed or screwed, a padding of loose felt is placed between the panel and the bows or ribs.

After the shaping process already mentioned, the entire roof is covered either with glazed duck or with plain sheeting. The glazed duck is already finished, and need not be glued to the roof. However, the sheeting is easily glued to the roof-panel and is inexpensive, except that it requires a fairly good paint finish. A roof so constructed is light and durable, and affords a reliable watershed. In case the cloth covering is torn or ruptured, and this is unlikely because the roof-panel itself takes all the stresses, the panel itself will shed water; this saves the upholstering and the interior furnishings of the car until such time as the roof covering can be repaired. This construction absolutely prevents the buckling or wrinkling of the roof covering.

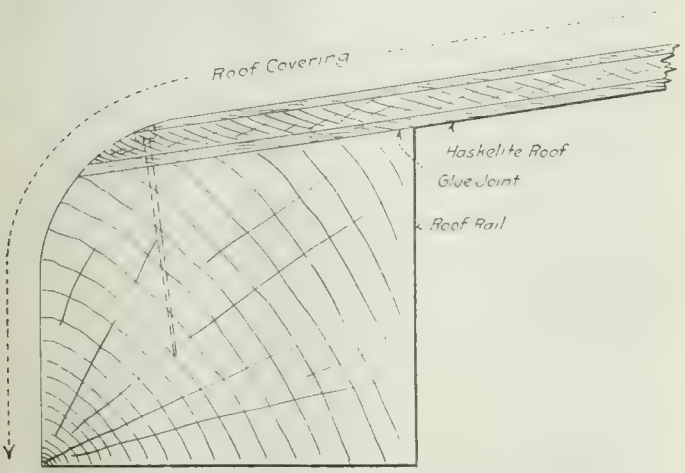

Fig. 6—Cross-Section of Taxicab Roof Showing Method of Attaching Panel to Rail

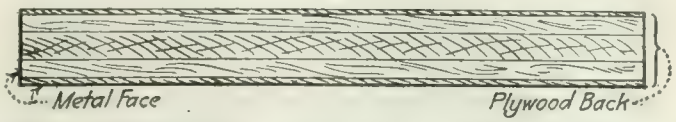

Fig. 7—Cross-Section of a New Type of Instrument Board, Showing the Plymetal Construction Recently Adopted by Several Large Body-Builders

This last point brings us to a consideration of the grade of plywood that is satisfactory for roof-panels. The plywood bonded by animal glue is not suitable. Expensive experience has shown that much. The waterproof plywood is recognized as the standard for roofs.

Types of Dash and Instrument-Board

In like manner, the waterproof panel of highest grade has found wide favor for dashes. It fills most of the needs of the dash, and a dash has many functions. It should act as a heat barrier, should deaden sound or vibration and act as a structural part of the body. The steel dash fails on several counts; it tends to rust, the bolt fastenings work loose and it is difficult to remove and replace if spot-welded in place. This point of replacement must be considered at all times in taxicab-body construction, as contrasted with passenger-car design.

A new type of instrument-board is shown in Fig. 7. This board of plywood and metal is easily fabricated, and combines all of the advantages of the pressed-steel wood-backed combination. The metal face, glued to the plywood back, can be bent over one end of the board.

Costs and Records

The cost of a taxicab body is about 40 per cent of the total cost of the cab. It is not amiss, therefore, to lay due stress on proper body-design and construction. In fact, it is of more importance than the cost proportion.

The keeping of accurate and comparable records by taxicab operators is proving of great value in the improvement of taxicab construction. Every failure of parts is a lesson, and points the way to improvement. Here is firm ground for the progressive engineer.

Present conditions can be summarized as follows:

(1) The severe service rendered by the taxicab requires the most durable type of body construction
(2) Proper joining of the frame members is of the utmost importance in producing a serviceable body
(3) The plywood molded-roof of the waterproof type is of accepted merit for taxicabs
(4) The body should be of such construction as to allow the easy replacement of parts

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Summary of Nail-Pulling Tests. Forest Products Laboratory, Aug. 5, 1919.

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Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

WAVE TRANSMISSION OF POWER

ARTICLES have appeared recently in a number of foreign journals[1] describing a comparatively new development in power transmission that may be of interest as offering another possible solution of certain automotive transmission problems. Although the more obvious applications appear to be in such operations as rock drilling, riveting, punching, etc., it is claimed that the method has been successfully applied to the transmission of power from an engine to the propeller both in marine and in aeronautical installations. If these claims are substantiated, the method may have a much wider application than appears at first sight.

The methods of transmitting power that are in commercial use at the present time may be divided into five classes, as follows: steam, direct mechanical, electrical, compressed air and hydraulic. What is claimed to be a sixth method employs wave motions or pulsations set up in an enclosed column of liquid, the power being transmitted as a result of waves of the compressed fluid traveling at the speed of sound. The principles underlying this wave transmission of power are said to be wholly different from those governing hydraulic transmission, for in hydraulics, as commonly understood, a continuous flow of liquid is used, while in wave transmission there is no direct flow.

The first instance of power transmission by a pulsating column of liquid is found in the synchronizing interrupter gear for airplane machine guns, invented by George Constantinesco. The same inventor has also developed a new rock-drill actuated by impulses transmitted through a flexible pipe-line filled with water. This new rock-drill has been

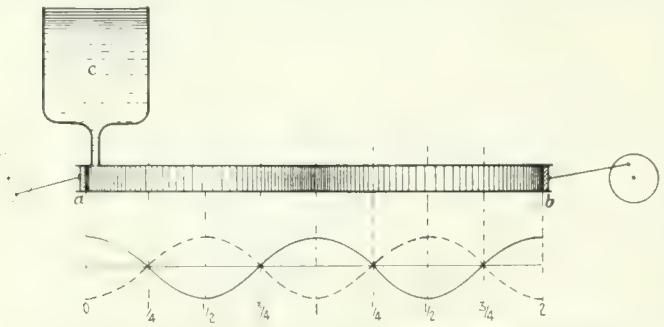


DIAGRAM ILLUSTRATING THE WAVE TRANSMISSION OF POWER

reported to be operating satisfactorily and to be doing its work faster and cheaper than is possible with the standard compressed air drills. In view of this accomplishment, an outline of the method of operation of this novel system of transmission may be of interest, especially as its promoters have announced that another development is under way for utilizing the characteristics of wave motion in the field of automotive engineering.

If a water-tight piston is pushed slowly into a pipe completely filled with water, the column of water may be regarded as a connecting rod that imparts the slow motion of the piston at *a* to the piston rod *b* at the other end of the pipe. During this transmission of the pressure from *a* to *b*, the column of water is slightly compressed, but the pressure throughout the column of water is everywhere uniform and all parts of the water column have everywhere the same direction and velocity of motion. If the piston *a* is now given a fast reciprocating motion, the inertia of the long column of water will interfere with the simple connecting-rod action just described and instead there will be local compression and rarefaction of the layer next to the piston *a;* this layer of compression will move through the column of water according to the laws for the propagation of elastic disturbances in liquids. In contradistinction to the simple hydraulic case, the distribution of pressure is no longer uniform throughout the length of the column of water, but varies as shown by the shading in Fig. 1.

The compression waves thus formed are progressive, that is, the compressed layers, spaced one wave-length apart, are propagated along the column of water at a velocity given by the formula:

$$v = ge/D$$

where

D = the density of the liquid or its weight per cubic foot.

e = the modulus of compressional elasticity in pounds per square foot.

$g = 32.2$

Calculating e from the compressibility of water, which is 0.000047 per atmosphere, gives 4800 ft. per sec. for the velocity of the compressional waves in water.

There is a complication in case the motor does not absorb all the power delivered by the generator. To see what happens under these conditions, let us take the extreme case where the piston *b* is held stationary, or where the end of the tube is closed. Then the compressional waves on reaching *b* are reflected and the reflected waves combine with the original waves to form standing waves. The sinuous curves in Fig. 1 show the pressure variations at any cross-section of the column of water after a standing wave has been established. The characteristic thing about a standing wave is that the layer of liquid in each cross-section of the column goes through a cycle of pressures and a cycle of motions depending upon its relative position in the wave. Thus, at the ends and at the middle of each wave-length there is the greatest range of pressure change, coupled with the minimum velocity range; at one-fourth and three-fourths wave-length the pressure change is zero, but the velocity change in each period is a maximum.

When less power is taken from the line than is fed into it by the generator, there is danger that the amplitude of the resulting standing waves will steadily increase until the pressure becomes so high that the tube bursts. To obviate this difficulty, large reservoirs, indicated by *c* in Fig. 1, are placed at appropriate positions in the transmission line. These "hydraulic condensers," as they are called by Constantinesco, act similarly to electric condensers in an alternating-current electric-transmission line; that is, they absorb the energy not needed in maintaining wave motion and return excess energy to the generator.

The two installations of wave rock-drills, as described in the engineering journals, are designed to operate with a standing wave, and although the details of design are not divulged, it is implied that the mechanical advantage is gained by dimensioning the various parts according to the wave constants involved. Thus, the wave-generator speed is 2400 r.p.m., or 40 revolutions per sec., which, with a wave velocity of 4800 ft. per sec., as previously calculated, gives 4800 divided by 40, or 120 ft. for the wave-length. Agreeing with

[1] See *The Engineer* (London), Oct. 27, 1922, p. 444; and Nov. 3, 1922, p. 446; see also A Treatise on Transmission of Power by Vibration, by George Constantinesco, published by Walter Haddon & Co., London.

this calculation, the length of the transmission line is 60 ft., or half a wave-length. Reference to the sinuous curve of Fig. 1 shows that with this length of pipe the hammer of the drill is located at a point where the pressure variations in the standing wave are greatest, and it is stated that the drill will operate only so long as this relation between the wave-length and the position of the hammer is held to within 5 per cent.

Another feature of the rock-drill that depends upon the characteristics of wave-motion is the dependence on resonance, that is, on tuning as it is practised in radio. In developing his theory Constantinesco derives formulas that are practically identical with those holding for the relations in alternating-current electric circuits; thus, there are terms containing C, the capacity of hydraulic condensers, depending upon elastic properties either of spiral springs or of hydraulic compressibility. There are also terms in L, corresponding to the coefficient of induction, which, for liquid waves is represented by inertia, that is, by mass or weight.

In any case of wave motion, there is resonance between two circuits when the periods $n = 1/[2\pi\sqrt{(LC)}]$ are multiples; tuning consists in varying C or L or both, until the resonance is attained. In the rock-drill the inertia, L, of the hammer, and the hydraulic capacity C of the chamber in which the hammer moves, are adjusted according to the formula just given until there is resonance with the transmission line, and furthermore, the conditions for maximum impact, as determined theoretically, are said to be embodied in the design of the rock-drill and to be responsible, in a great measure, for its favorable performance. There are no published experimental data from which to judge the degree to which the theoretical deductions are realized in practice, but if we take in good faith the claims of the inventor and of the manufacturers, we should expect that this new system of power transmission could be applied with advantage to operations involving percussion, as, for example, in riveting machines and piledrivers. As an example of this type of application to internal-combustion engineering, the manufacturers cite a valve-actuating device that has been used successfully on a large marine Diesel engine for operating the fuel, inlet and exhaust-valves.

While the standing-wave type of liquid transmission thus seems peculiarly adapted to the operation of a percussion machine, it is easy to see that the very close regulation required for resonance makes this method impracticable for driving a number of motors at variable loads from one generator. In this case, Constantinesco proposes rotary motors that are capable of utilizing the energy of what we have called progressive waves. The theory of power transmission by progressive waves is strikingly similar to the theory of power transmission by alternating electrical currents, and involves, besides the constants R and C already mentioned, the hydraulic analogues of resistance, leak, step-up and step-down transformers, power factor and other terms familiar to the electrical engineer. For the rotary motor, also, this parallelism between wave-transmission and alternating-current electrical machines is very close. The motor may be a single-phase synchronous machine, which, like its electrical analogue, can be started only after it has been brought into step with the generator, and it can be operated on only a narrow range of speeds and loads. A synchronous alternating-current electrical motors were made possible by the use of three-phase systems and the polyphase idea was then adapted to single-phase systems by the use of a phase-splitting device for starting. Similarly, wave-motors are to be constructed for operation with progressive waves transmitted through a single line of pipe or through a system of three pipes, corresponding to single and three-phase alternating-current motors, and, furthermore, these motors may be built as synchronous or as asynchronous machines.

The manufacturer of the wave transmission equipment states that it has constructed for the British Government two power-transmitting units of the three-phase type; one for driving the propeller of a warship, and the other for driving the two propellers of a twin-screw airplane from one engine. It also intimates that a trial of this rotary motor in a railcar is contemplated. These and other projected applications of the progressive-wave type of wave-transmission have evidently not reached the stage where results can be made public, and it would be futile to speculate concerning either the correctness of the underlying theory, or the practical significance of the proposed method of transmission.

MIDGLEY RECEIVES THE NICHOLS MEDAL

THE Nichols medal is awarded annually for the best original paper published during the preceding year in one of the three journals of the American Chemical Society. This year the honor was awarded unanimously to to Mr. Midgley's article on the Chemical Control of Gaseous Detonation With Particular Reference to the Internal-Combustion Engine.

Mr. Midgley's address of acceptance, entitled Some Fundamental Relations Among the Elements and Compounds as Regards the Suppression of Gaseous Detonation, dealt with the chemical aspects of "anti-knock," that he defined as "a property of matter whereby a material acts as either a negative or a positive catalyst in the prevention of detonation in the internal-combustion engine." Mr. Midgley exhibited numerical data and graphical summaries for the anti-knock properties of 22 of the chemical elements. For instance, Table 1 illustrates how the anti-knock value changes for the most important of these elements.

TABLE 1—COMPARISON OF RELATIVE EFFECTS EXERTED UPON DETONATION BY ETHYL AND PHENYL COMPOUNDS OF FOUR ELEMENTS

Element	Reciprocal of Number of Grams To Give Anti-Knock Effect Ethyl Compound	Molecules Required Equivalent to One Gram-Molecule of Aniline[a] Phenyl Compound
Iodine	1.090	0.88
Selenium	6.900	5.20
Tellurium	26.800	22.00
Oxygen	— 0.036[b]	....

[a] Based on concentration of aniline up to 3 per cent by volume in kerosene.

[b] Induces detonation.

Among the data presented in Mr. Midgley's address are the following values for the reaction velocity constant K determined for the kerosene and the apparatus used by Mr. Midgley and Robert Janeway in the experiments described in the April number of the JOURNAL:

Concentration Pb Et$_4$ Cc. per Gal.	K
0	3.250×10^{-7}
1	3.170×10^{-7}
2	3.075×10^{-7}
4	2.970×10^{-7}
8	2.860×10^{-7}
16	2.760×10^{-7}

The decrease of K with an increasing lead tetraethyl concentration is in a sense predicted by Mr. Midgley's theory, but it should be noted that, although these figures probably give a correct idea of the variation, they include an apparatus variable and therefore do not represent the absolute values of the reaction velocity constant.

The far-reaching chemical significance of Mr. Midgley's researches on detonation is clearly expressed in this award to an automotive engineer of a prize much coveted by American chemists. This incident illustrates, furthermore, how research in one field often leads to results of the greatest importance in some apparently unrelated field, and the automotive industry, in congratulating Mr. Midgley on the signal honor bestowed on him, may well feel proud of its contribution to chemical science.

TENTATIVE STANDARDIZATION WORK

Criticism of all tentative reports should be sent to the Standards Committee in care of the Society

SIX-POINT CARBON RANGE PROPOSED

Iron and Steel Division to Consider Specifying Closer Limits for Steels

The Iron and Steel Division has been asked by a metallurgist connected with one of the larger automobile producers to consider revising the present S. A. E. Iron and Steel Specifications so as to specify, among other requirements, a six-point carbon range for alloy steels.

For many years the steel producers have been controlling their product so that the carbon-content has come within the range of 10 points (0.10 per cent) specified in the present S. A. E. Iron and Steel Specifications. Closer ranges have not been attempted, as it was recognized by the users as well as by the producers that such refinements would mean an increase in the cost of the steel. A few of the larger companies have, however, decided as a result of experience that for certain parts closer limits than those specified in the present S. A. E. Steel Standards are desirable. As they are purchasing in large quantities, it is possible for them to obtain closer limits through the use of resident inspectors at the mill. As it is impractical to use two methods of numbering steel in one plant, companies desiring steel made to closer limits have used their own specification numbers rather than the S. A. E. Specification numbers. It has therefore been suggested that the present method of numbering S. A. E. Steels be changed to a system that would make it possible to specify any steel composition. The suggestions that have been submitted to the Iron and Steel Division for consideration are given herewith.

(1) The carbon range of 10 points for all carbon steels to remain as at present

(2) The manganese range for all carbon steels to be 30 points

(3) The same sulphur and phosphorus limits to be specified for all carbon steels

(4) The same silicon limits to be specified for all carbon steels

(5) The carbon range for all alloy-steels to be 6 points

(6) The manganese range for all alloy-steels to be 20 points

(7) The same nickel range to be specified for all nickel, nickel-chromium or nickel-molybdenum steels

(8) The same chromium range to be specified for all chromium vanadium, nickel-chromium or chromium-molybdenum steels

(9) The same sulphur and phosphorus content to be specified for all alloy-steels

(10) The same molybdenum and vanadium ranges to be specified for all alloy-steels

(11) The adoption of a more comprehensive system of numbering

In reference to the adoption of a more comprehensive system of numbering the following system was suggested:

The first two digits of the specification number should designate the classification of the steel as at present. The next two digits should designate the carbon-content desired, and the last two digits the manganese-content desired. S. A. E. Steel No. 103865 would then indicate a carbon steel of 0.38 per cent carbon, 10 points variation (0.33-0.43) and 0.65 per cent manganese, 30 points variation (0.50-0.80). The sulphur and phosphorus content would be standard as well as the silicon. S. A. E. Steel No. 333070 would indicate a nickel-chromium steel of standard nickel and chromium content, with carbon 0.30 per cent, 6 points variation (0.27-0.33) and manganese 0.70 per cent, 20 points variation (0.60-0.80). The sulphur and phosphorus-content would be standard as well as the silicon.

With the proposed system it would be possible to specify any grade of steel with any percentage of carbon or manganese that is desired for a given requirement. It would also be possible for all users of steel outside of the automotive industry to apply their particular analyses to the system.

WHEEL MOUNTINGS CRITICIZED

As a result of several criticisms in reference to the wheel mounting recommendation made by the Axle and Wheels Division and now printed on p. F1c of the S. A. E. HANDBOOK, the dimensions specified in the present standard, together with the supplementary dimensions that were approved by the Division at a recent meeting, will be laid out to scale and blueprints of the layout sent to members of the Division for study. If it is found after careful analysis that changes in the present standard or in the supplementary dimensions proposed are advisable, such changes will be recommended by the Division at the Summer Meeting of the Standards Committee.

HARDWOOD LUMBER SURVEY UNDER WAY

With the arrival of two representatives of the Forest Products Laboratories at the plant of the Fisher Body Corporation in Detroit, the program of the Passenger-Car Body Division on the standardization of hardwood lumber in cooperation with the Central Committee on Lumber Standards and its consulting committee was considered to be well under way. The representatives working with R. E. Brown of the Fisher Body Corporation, who is a member of the S. A. E. Subdivision on Hardwood Lumber Standardization, will make a careful survey of the hardwood lumber requirements of his company with the idea of working out plans that may be extended to other body companies in determining the requirements of the automotive industry for factory cut-up sizes of hardwood lumber of body framing.

The lumber standardization program was initiated at a conference held in Washington at the request of Secretary Hoover, the Central Committee of Lumber Standards being organized at that time to formulate American standards for the sizes of lumber and methods of grading so as to place the industry on a more efficient basis for the conservation of the lumber supply through the elimination of the wastage and misunderstanding resulting from present practice. The Central Committee on Lumber Standards is representative of the lumber producer, the jobbers, the consuming interests and the national engineering societies. A consulting committee that is advisory to the Central Committee is composed of representatives of the several branches of the lumber-producing industries, particularly the consuming industries and the national standardization bodies. The Society is

represented on the consulting committee by R. E. Brown, of the Fisher Body Corporation.

To further the work of the consulting committee with special reference to the automotive industry, the Society organized a Subdivision to facilitate the gathering of specific data from the body builders. The personnel of the Subdivision is as follows:

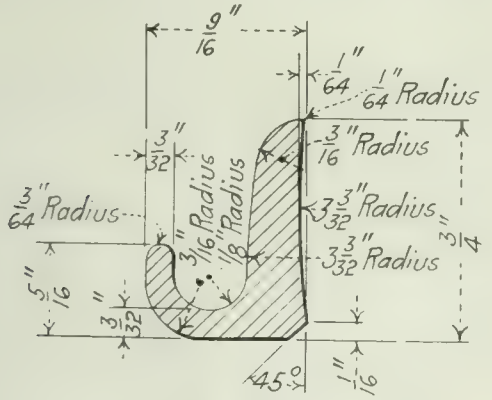
G. J. Mercer, *Chairman*	Consulting Engineer
R. E. Brown	Fisher Body Corporation
R. A. LaBarre	Towson Body Co.
T. J. Litle, Jr.	Ford Motor Co.
F. F. Murray	Hardwood Manufacturers' Institute
J. E. Schipper	Class Journal Co.
A. T. Upson	Forest Products Laboratories

ALUMINUM MOLDING STANDARDS NEEDED

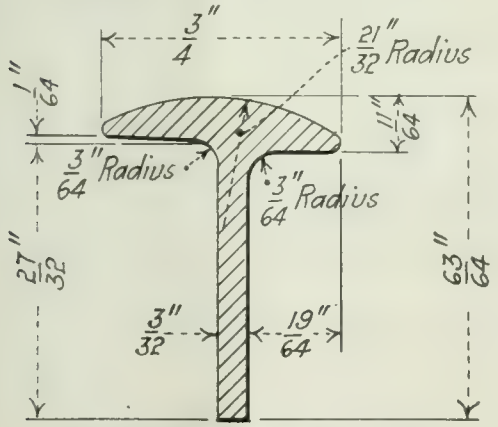
Range of Types and Sizes Now Used Heavy Burden on Manufacturers

The Subdivision on Aluminum Molding, which was appointed by Passenger-Car Body Division in 1922, has submitted a progress report that is given in full in the accompanying tables and illustrations. The report has been submitted for criticism to the body builders and to the passenger-car companies building bodies.

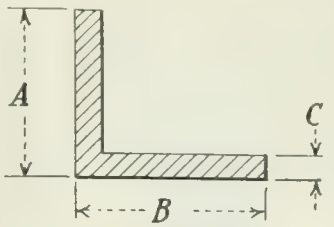
The adoption of standard aluminum moldings in actual production will eliminate the great variety of types and sizes that are used in the industry today and necessitate an unnecessarily large investment in tools and stock which increases the cost of production. The types and sizes of molding proposed by the Subdivision are considered more or less standard at the present time and it is believed that they will meet normal future requirements, the standards being intended for adoption only when changes in production and design economically permit.



DRIP MOLDING
Estimated Weight—0.180 Lb. per Ft.

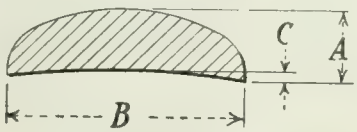


TEE MOLDING
Estimated Weight—0.188 Lb. per Ft.



DIMENSIONS FOR ELL MOLDING

No.	A	B	C	Estimated Weight, Lb. per Ft.
1	¾	¾	⅛	0.238
2	1	1	3/16	0.455
3	1¼	1¼	¼	0.791
4	1½	1½	¼	0.954
5	2	2	¼	1.280
6	2½	2½	¼	1.607



DIMENSIONS FOR BELT MOLDING

No.	A	B	C	Estimated Weight, Lb. per Ft.
1	3/16	⅝	0.019	0.107
2	3/16	¾	0.020	0.117
3	3/16	½	0.019	0.086
4	¼	1	0.025	0.228
5	¼	⅞	0.025	0.186
6	¼	1¼	0.025	0.286
7	5/16	1¼	0.030	0.300

FELT SPECIFICATIONS APPROVED

Thirteen Classifications of Felt Included in Report of Subdivision

Although there has been a wide difference of opinion as to the possibility of formulating practical specifications for felt, the Subdivision of the S. A. E. Parts and Fittings Division that was appointed some time ago to consider the practicability of formulating felt specifications has submitted a preliminary report covering the specifications that are considered to meet the requirements of the automotive industry.

Whether or not these specifications are satisfactory for adoption as S. A. E. Recommended Practice or as S. A. E. Standard will be decided largely by the consensus of opinion of felt users as determined by a general letter that has been sent to passenger-car, motor-truck and axle manufacturers.

To determine the percentage of wool, the following method abstracted from Sadtler's Industrial Organic Chemistry should be used

> Boil a 2-gram sample of the material to be tested in 60 to 80 cc. of sodium-hydroxide solution of 1.02 specific gravity for 15 min., using a reflux condenser. Wash the residue with distilled water until the sodium-hydroxide and the saponified wool are removed, then press out the water, dry in air and weigh.
>
> $$\text{Per Cent Wool} = 100\ (W - 1.05\ w) \div W$$
>
> where
>
> W = the weight of the original sample
> w = the weight of the residue
>
> Since hair and other animal fibers similar to wool will be saponified and included in the resulting percentage, a microscopic examination should be made of the original sample.

All of the above grades of felt shall be free from starch, glue or other artificial binders unless otherwise specified.

TABLE 1—PROPOSED FELT SPECIFICATIONS

Specification No.	Classification	Wool, Per Cent	Remaining Ash, Per Cent	Color	Thickness Tolerance, Plus or Minus, Per Cent
F1	Back Check	100	1.00	White	10
F2	Back Check	100	1.00	Any Color	10
F3	Back Check	95–100	1.25	Any Color	10
F10	Firm Pad	100	1.00	White	10
F11	Firm Pad	100	1.25	Grey	10
F12	Firm Pad	90–95	1.25	Grey	10
F13	Firm Pad	80–85	1.25	Grey	10
F15	Firm Pad	60–65	1.50	Grey	10
F26	Soft Pad	50–55	1.50	Grey	10
F30	Medium Sheet	100	1.25	White	5
F50	Colored Shoe Upper	100	1.25	All Colors	10
F51	Shoe Upper	70	1.25	Grey and Black	15
F60	Asbestos	50[a]	5.00	Grey	15

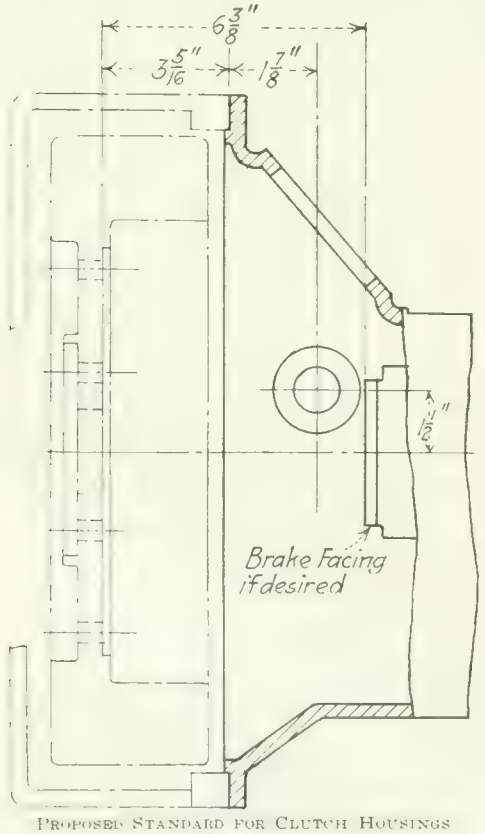
[a] 50 per cent reworked wool and 50 per cent wool substitutes.

TABLE 2—THICKNESS AND WEIGHT OF PROPOSED STANDARD FELTS

Specification No	Weight of Felt, Lb. per Sq. Yd. Allowable Tolerance, Plus or Minus 10 Per Cent — Felt Thickness, In.									
	1/8	3/16	1/4	5/16	3/8	1/2	3/4	1	1 1/2	2
F1	2.00	3.00	3.95	5.10	6.00	8.20	...	....	....	....
F2	2.00	3.00	3.95	5.10	6.00	8.20	....	....	....	....
F3	2.00	3.00	3.95	5.10	6.00	8.20	....	....	....	....
F10	1.50	1.75	2.25	2.75	3.25	4.25	....	....	....	....
F11	1.50	1.75	2.25	2.75	3.25	4.25	.	.	....	....
F12	1.50	1.75	2.25	2.75	3.25	4.25	.	.	....	....
F13	1.50	1.75	2.25	2.75	3.25	4.25	. .	....	....	....
F15	1.50	1.75	2.25	2.75	3.25	4.25	. .	....	....	....
F26	1.10	1.50	1.90	...	....	....	. .	....	....	....
F30	....	.	5.00	. . .	7.50	10.00[a]	17.50	20.00	30.00	40.00
F50[b]	....	....	. . .	....	....	...	....	....	....	....
F51[c]	....	....	...	....	....	....	....	....	....	....
F60	. . .	....	1.50	....	2.25	3.00	4.50	6.00	....	....

[a] Specification No. F50 shall weigh 20 oz. per yd. 60 in. wide when 0.050 in. thick; 22 oz. when 0.055 in. thick; 24 oz. when 0.060 in. thick, 26 oz. when 0.065 in. thick, 28 oz. when 0.070 in. thick; 30 oz. when 0.075 in. thick; 32 oz. when 0.080 in. thick and 34 oz. when 0.085 in. thick.

[c] Specification No. F51 shall weigh 6 oz. per yd. 60 in. wide when 1/32 in. thick; 10 oz. when 3/64 in. thick; 14 oz. when 1/16 in. thick and 18 oz. when 5/64 in. thick.



PROPOSED STANDARD FOR CLUTCH HOUSINGS

All weights shall be based on the thickness of the felt as ordered and no correction in weight shall be made for variations in the thickness of the material received.

The appearance, hardness, and oil-absorption qualities shall be in accordance with a sample of felt approved by the engineering department and retained as a standard by the purchasing and inspection departments.

General Information.—Back check and firm pad felts are recommended for use in washers, bushings, oiling wicks, door bumpers and similar parts.

Soft pad felt is intended for chassis strips. Medium sheet felt is intended for use where a felt harder than back check felt is required.

Colored shoe upper felt is intended for use for ball and roller bearing oil-retainer washers and for use where an accurate, thin, smooth, high-grade felt is desired.

Shoe upper felt is intended for use where a felt thinner than back check or pad felt is required and where the higher quality of colored shoe upper felt is not required.

Asbestos felt is intended for such applications as soft top padding or cushions.

CLUTCH STANDARDS PROPOSED

Housings Satisfactory for Both Single-Plate and Multiple-Disc Clutches

For some time the Subdivision on Clutch Standardization has been considering the possibility of standardizing clutch housings so as to permit interchangeability of different makes of multiple-disc and single-plate clutch. The dimen-

sions, the standardization of which is considered necessary to obtain such interchangeability, are

(1) The distance from the flywheel face to the rear throw-out position of the clutch sleeve
(2) The position of the throw-out yoke for the pull-sleeve type of clutch.

In determining upon satisfactory dimensions, it was recognized that the greater the distance from the flywheel to the rear throw-out position, the greater the weight of the housing, and the consequent overhang of the transmission, which would work a decided hardship on the large producers of small and medium-size cars. A dimension of 6⅝ in. was therefore selected as shown in the accompanying illustration.

The 1⅞ and 1½-in. dimensions proposed for the location of the throw-out yoke were selected as providing a satisfactory position, which at the same time would permit a reasonable pedal ratio for both multiple-disc and single-plate clutches.

Although it is recognized by the Subdivision that the trend among large producers is to make the overall clutch length much less than recommended by the Subdivision, it is considered desirable to present the above recommendation because it would greatly simplify the problems of the transmission and clutch manufacturers and thus work to the advantage of the greatest number of car producers. The Subdivision will, however, endeavor to establish a standard for the short clutch housing.

DOOR-HINGE STANDARDIZATION FAVORED

Comments received from passenger-car body builders in reference to the Subdivision recommendations for door-hinges indicate that with slight revisions the recommendation will be acceptable to the body industry. It is therefore anticipated that the Passenger-Car Body Division will be in a position to make a definite recommendation on this subject to the Standards Committee at the Summer Meeting that will be held at Spring Lake, N. J., June 19.

THE SOCIETY IN AUSTRALIA

THE following letter from the Associated Trade Journals Co. of Sydney, Australia, is of interest as indicating the ever-increasing sphere of the Society's work and the appreciation of our foreign associates of what the Society is endeavoring to accomplish for the industries through the S.A.E. standardization.

Sydney, 2nd March, 1923.

Society of Automotive Engineers, Inc., New York.

We have to acknowledge the receipt of your letter of 15th December, and to advise that the S. A. E. Standards and Recommended Practices duly came to hand, together with the other publications mentioned by you.

We have to thank you sincerely for your permission to reproduce a selection of these Standards, and believe that your help in this matter will be productive of good results both in Australia and in your country; not only will it assist the manufacturing engineer in the growing motor industry here, but it will help to show our people the careful and thorough consideration that has been given to these matters in the United States.

Apart from this will you accept our congratulations, both upon the wide area you have covered and upon the thoroughness with which you have dealt with the many problems.

We are very interested in the work being accomplished by your Society and would like to keep in close touch with your activities. But it is not easy to see just how our activities fit in with a plan of operation. We certainly wish to receive your monthly JOURNAL, and all standards, etc., as issued.

Although Australia, the "South Sea Empire," is not a large manufacturing country comparatively as yet, it is a land of wonderful natural resources and is working toward a leading position in industrial activities. The following figures[1] indicate the rapidly increasing importance of Australia as a prospective buyer of automotive vehicles.

AUTOMOBILES EXPORTED TO AUSTRALIA

Year	Passenger Cars Number	Passenger Cars Value	Trucks Number	Trucks Value
1913	2,083	$1,896,990	17	$23,027
1914	3,099	2,615,896	32	37,378
1915	2,169	1,768,479	57	84,142
1916	5,335	4,147,302	201	295,538
1917	5,055	3,792,571	194	237,159
1918	4,307	3,410,557	109	163,405
1919	3,905	4,016,751	418	565,406
1920	8,989	10,034,626	985	1,436,589
1921	3,020	3,065,890	720	1,194,900
1922	11,236	8,716,930	1,095	1,211,199

[1] These figures were obtained from the National Automobile Chamber of Commerce and do not include New Zealand.

The producers of vehicles exported to Australia bear the responsibility of building into their product units, accessories and materials that will enable the purchasers to get maximum life and economical operation. The servicing of these vehicles in a so distant land is of prime importance and the vehicle builders can render their users the best service in the replacement of parts in the least time and at lowest cost by using the Standards that the Society of Automotive Engineers has been formulating and publishing for many years in the S. A. E. HANDBOOK.

METRIC TIRE-SIZES

A COMPARISON of the statistics of export shipments of automobile tires compiled by the Rubber Association of America, Inc., with the official customs returns for 1922, shows that roughly 75 per cent of the exports are reported to the Rubber Association. Of this 75 per cent, the proportions of metric sizes exported are casings, 24 per cent; tubes, 14 per cent; and solid tires, 20 per cent.

It is said that the tendency is toward the use of straight-side tire equipment on European cars. The thorough adoption of cord tires in metric sizes by leading European builders is a step in this direction, because of the difficulty of making satisfactory extensible beads for cord casings, and the non-extensible straight-side bead is the logical solution. The facts that Rolls Royce has adopted straight-side equipment as standard and that all winners of recent classical road-races used straight-side tires are additional evidence of the general tendency toward the increasing use of this type of tire throughout the world.

SOCIETY MEETINGS

AUTO TRANSPORT MEETING SUCCESSFUL

Trucking, Bus and Taxicab Papers Reflect Advance of Engineering in Operating Field

The development of sound motor-transport engineering principles received great impetus at the first Automotive Transportation Meeting of the Society in Cleveland April 26 to 28. Close to 200 persons from all sections of the Country and all branches of the transportation field were in attendance. The keynote of the meeting was the promotion of a better understanding between the operators of the railroads and electric railways on the one hand and the automotive industry on the other. It is fortunate that the Society should devote a national meeting to motor-transport problems at a time when the motor truck and the motorbus are just beginning to be accepted as highly valuable accessories to the railroad and the street car instead of being regarded as their pernicious competitors. It was clearly evident, as one listened to the papers and discussion that motor transport is an established arm of the Nation's transportation system; basic fundamentals of operation are not established definitely as yet, but successful applications, such as those described at the meeting, are bringing the problems and their solutions to the surface. This will result eventually in the establishment of automotive transportation engineering as a distinct and important science. The Cleveland meeting represents the Society's effort to interest engineers in the development of this science and to attract into its membership those motor transport experts who are pioneering this development in order that they may be closely associated with the designers and producers of the vehicles used in their operations.

The meeting program included four professional sessions, a group of factory visits and a dinner. Seven of the nine papers read at the sessions are printed in full in this issue of THE JOURNAL. The following pages contain a resume of the discussions of the papers and a report of the addresses at the Transportation Dinner.

TRUCK AXLE EFFICIENCIES COMPARED

Bureau of Standards Tests Show Triple-Reduction Type Has Lowest Overall Power Loss

The Thursday morning meeting was opened with a paper on axle efficiencies prepared and read by S. Von Ammon of the Bureau of Standards staff. The data and conclusions were the result of an extensive group of tests undertaken by the Bureau for the Motor Transport Corps with the object of determining which type of rear axle was best suited to the service and operating conditions encountered by the vehicles used in the transportation of Army materiel. The tests were limited to heavy axles, capable of duty under trucks of the 5-ton class. Eight axles were tested and included representative worm, double-reduction, triple-reduction and internal-gear types. The tests were made by driving the axles with an electric dynamometer through a standard Class B Army truck transmission rigidly mounted on the field frame of the electric dynamometer. The power output was absorbed by prony brakes at the rear wheels. The differentials were locked during the tests by filling them with soft metal and the brake mechanism was removed to avoid brake-drag losses. Each of the axles was run for a sufficient time previous to the official runs to reduce, as far as possible, any change in mechanical fits during the actual tests.

The influence of oil temperature on the performance of the axles made it necessary to take observations at definite tem-

R. E. Fielder W. H. Lyford David Beecroft

THREE PROMINENT SPEAKERS IN THE DISCUSSION

peratures for each of the test runs. This resulted in the following program of tests being carried out.

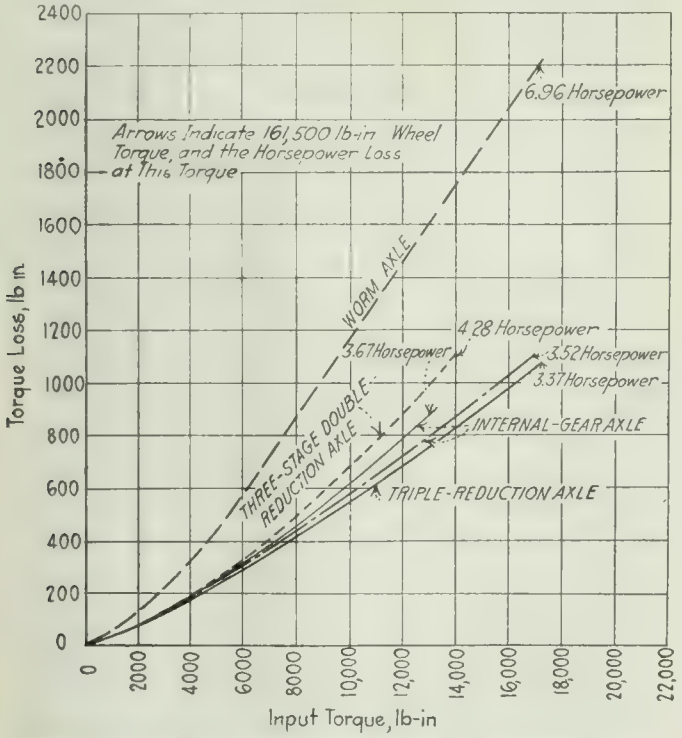
1. Preliminary power runs at 8.5 m.p.h. and various temperatures up to 100 deg. cent. (212 deg. fahr.).
2. Efficiency tests at six different speeds and several temperatures.
3. Temperature-rise run at 15 m.p.h. with a constant load of about 50 hp.
4. Check runs at 2.5 and 15 m.p.h. and a temperature of 70 deg. cent. (158 deg. fahr.).
5. No-load tests at several speeds and oil temperatures.
6. Break-down tests at 2.5 m.p.h. with a constant load of 50 hp. Oil-temperature rise observed.

Government specification lubricant was used and the oil level was kept constant throughout the tests.

In analyzing the results of the tests it was found possible to separate the losses into (a) no-load losses, and (b) load losses; the total losses are the sum of these two. In general, the no-load losses were primarily controlled by the viscosity and the method of applying the lubricant. They were greater in those axles where the parts rotating at high speeds were immersed most completely in the oil. Where a separate body of lubricant was used in the wheels, the losses were still greater. In a given axle these losses are increased with an increase in the viscosity of the lubricant and with the propeller-shaft speeds.

The load losses, expressed as torque, were practically independent of the speed and of the viscosity and the method of applying the lubricant. They increased, however, with an increase of the torque input and at an increasing rate. In the case of the Class B worm-type axles, the increase in the load losses with an increased torque-input was greater than with any of the gear-type axles. The use of a lubricant of a lower viscosity at low temperatures would improve the mechanical efficiency under the more unfavorable conditions of speed and temperature and would seem advisable. Some improvement in the method of circulating the oil is suggested as desirable by the results since the high no-load losses of some of the axles show the present method of circulation to be very inefficient.

The characteristic difference between the worm-drive and gear-drive types is demonstrated by the greater load losses of the former type. One of the curves taken from Mr. Von Ammon's paper is shown herewith to indicate the torque losses of the different axles with increasing torque input.



CURVES SHOWING HOW THE TORQUE LOSSES OF DIFFERENT TYPES OF REAR AXLE INCREASE WITH THE TORQUE INPUT

M. C. Horine asked why the conventional double-reduction axle, in which the primary reduction is through bevel gears and the final reduction is through a single pair of spur gears, was not tested. Also, why was the chain drive omitted? A. W. S. Herrington of the Motor Transport Corps replied that no axles of the former type were made in the heavy duty or five-ton class. The chain drive was omitted because it is not suitable for Army service in the judgment of the Motor Transport Corps engineers. Mr. Herrington warned those present that the results of the tests must be accepted as applying primarily to military service. The worm axles tested were designed to have a maximum road clearance and this limited the size of the worm gear. In the case where road clearance was not a factor the worm-wheel could be made large with the worm underneath; the conditions demanding low speed and high torque in military service might not prevail; silent operation might be a paramount condition. In such a case, the worm drive axle would appear to much better advantage.

Mr. Von Ammon's paper will appear in full in the June issue of THE JOURNAL.

MOTOR-TRUCK INDUSTRY IS SOUND

Exception Taken to Inference That Trucks Cannot Be Sold and Operated Profitably

In the paper read by S. G. Thompson at the Transportation Meeting exception was taken to the title of a pamphlet published recently by one of the trade papers which read, "What Is Wrong with the Motor-truck Industry?" Mr. Thompson's paper is printed in full on p. 446 of this issue. He reviews the history of the motor-truck industry, and the great changes in conditions of transportation demand are stated as conclusive proof that the motor truck is a permanent asset, that there is nothing wrong with the industry and that, to the contrary, the motor-truck industry is fundamentally right.

David Beecroft, publisher of the pamphlet in question, was present at the meeting and replied to Mr. Thompson in the discussion. He said that the title to the pamphlet had been chosen for the purpose of exciting interest in the text matter that contained no reflection on motor trucks or the industry. It is necessary that opinions be founded on text rather than titles. The text of the pamphlet was based on the user's point of view entirely; it represented an attempt to set down the problems facing the operator of motor vehicles as reflected in responses to a large number of questionnaires sent to 25,000 fleet operators all over the world. It was found that their transport problems are not problems of the vehicle, but are problems of transportation. Maintenance was the problem of 81 per cent of those who replied; organization troubled 74 per cent; cost determination was worrying 72 per cent; operating plans or control of the vehicle on the street interested 72 per cent; selection and handling of drivers was the problem of 69 per cent. This indicates that these operators are satisfied with their vehicles as a transport tool, but they are troubled with problems of organization and operation.

Later reports show that the problem of personnel stands highest; training and supervising drivers, loaders, helpers, inspectors and mechanics. Yesterday, under the horse ré-

gime, the horse was the yardstick by which a day's transportation service was measured. Fifteen miles was the limit of his daily travel and the driver's initiative counted for little. We now have a vehicle that, if properly maintained, can be operated nearly 24 hr. each day. The capacity of this new unit is limited only by the efficiency of the organization that sets it to work and keeps it working. This condition puts the burden of success on the choice and training of the proper personnel. Mr. Beecroft offered an apology to the industry for anything that might have been said in the pamphlet that could be construed as insinuating that the motor-truck industry was falling backward.

SUCCESSFUL RAIL-TERMINAL HAULAGE

Operations of St. Louis Firm Using Tractors and Semi-Trailers Described

A system of automotive transportation for intra-city hauling and the movement of freight between railroad terminals that has proved successful in St. Louis was described by J. F. Murphy in a paper read at the Thursday morning session of the Transportation Meeting. This paper is printed in full on p. 467 of this issue of THE JOURNAL.

A. F. Masury opened the discussion of Mr. Murphy's paper. He said that this operation represented a fitting example of the logic of fitting the truck to the business and the business to the truck. The success of the Columbia Terminals installation could be credited to four conditions; first, the hauling is done over routes between definitely located points and at a nearly uniform speed; second, the grade conditions are not severe; third, the loads carried are fairly near the full capacity at all times; fourth, the tractors are kept busy nearly all the time by the dispatching system used. The operation of gasoline-propelled tractors in connection with semi-trailers has received little support from truck builders. The possibility of being able to transport two to three times the load capacity of a truck without changing the power unit is most inviting, but there are many difficulties met in carrying the plan into operation. Many of these follow as a result of imperfections in the tractor, the trailer or the connection between the two. Mr. Masury felt that the future for such equipment does not lie entirely in city work, especially in view of the present tendency in highway legislation. The important thing to keep in mind is that the tractor-trailer combination will come within the requirements of highway laws, up to a much greater payload capacity than the four-wheel truck. Trailer brakes are essential to successful operation. Grade conditions must be surveyed carefully, and the prospective load capacity determined accurately, before choosing equipment for interurban work.

Francis W. Davis said that there were a dozen other cities where conditions warranted the establishment of installations similar to that in St. Louis. It is reported to cost $35 to deliver a car in the Borough of Manhattan, New York City, after it has reached the Jersey City terminal. The very magnitude of the problem, along with the desire for cautious procedure until the most practical and lasting system has been developed, probably furnishes the inertia that prevents the immediate institution of adequate intra-city transfer motor lines in the New York City area. Mr. Davis compared the St. Louis or semi-trailer plan with the installation in Cincinnati, which is operated on the demountable truck-body plan, and cited the following advantages that led him to favor the St. Louis system:

(1) Capital invested
  - (*a*) Motive power in relation to tonnage capacity
  - (*b*) Terminal costs, both on-track and off-track
  - (*c*) Extra cost of trailers as compared with unit bodies is probably offset entirely due to the heavy construction necessary with unit bodies and the necessary overhead apparatus at all terminal points for handling

(2) Operating expense
  - (*a*) Decrease in insurance of motive power in relation to tonnage capacity
  - (*b*) Decrease in fuel consumption in relation to tonnage capacity
  - (*c*) Decrease in labor cost both in relation to motive power and at terminals
  - (*d*) Decrease in upkeep and maintenance of motive power in relation to tonnage capacity

(3) Flexibility
  - (*a*) Saving in time at terminal points as driver controls picking up and letting go of semi-trailers from the seat
  - (*b*) Takes up less road space in relation to tonnage hauled
  - (*c*) Increasing rather than decreasing platform space

The one point wherein the unit demountable body seems to have an advantage over the semi-trailer is in the proposed shipment on line-hauls of the loaded bodies or unit containers, thus obviating terminal labor costs and other handling expense. Mr. Davis was of the opinion that, even here, there was nothing to prevent lifting the body from the semi-trailer as used at St. Louis. He considered that users of motor-truck equipment in other fields than terminal haulage will do well to study the results obtained in St. Louis, as the tractor-trailer unit stands ready to effect economies and handle tonnage far beyond the results accomplished to date.

Asked regarding the possibilities of night service, Mr. Murphy replied, that this was impractical because the rail terminals did not operate at night and the merchants would not be open to take deliveries. His company is able to handle 80 to 90 per cent of the total interchange of less-than-carload freight reaching St. Louis from the East and the West, so that it is delivered to the connecting railroad and started out the same day. This enables the railroads to get efficient and complete loading of cars and increases the area in which St. Louis merchants are able to carry on business. Mr. Murphy did not favor the demountable-body scheme of motor haulage in his work because the bodies took up loading platform space at both the terminals and the warehouse. Just as soon as the loading platform is congested, costs begin to mount. In closing, Mr. Murphy stated that he and his engineer, Mr. Englander, who is responsible for the system employed by the Columbia Terminals Co., would be glad to contribute anything further that they could, for the advancement of motor transportation.

TERMINAL TRUCKING AND CARTAGE

Motor-Truck Session Takes-Up Congestion at Terminals and Store-Door Delivery

The second Motor Truck Session was called to order at 2 o'clock on Thursday afternoon by Chairman F. W. Davis. The first paper, by F. C. Horner of the General Motors Corporation, who discussed English Cartage Practice, a Standard for Our Railway-Terminal Trucking, is printed in full on p. 437 of this issue of THE JOURNAL. In opening the discussion of Mr. Horner's paper, Chairman Davis called attention to the advanced stage of development of the English

system of handling terminal shipments and from store-door to terminal traffic. He referred to the fact that Elisha Lee of the Pennsylvania Railroad system had voiced the sentiment at the annual dinner of the Society that the railroads of this Country at least are very much opposed to the possibility of having this operation, which implies ownership, forced upon them, and inquired whether the service had been forced on the English railroads or they voluntarily took it over as a profit-returning venture. Mr. Horner replied that the English railroads were not required by law to adopt it but that they were forced to do so because they could not get service from the existing cartage agencies. He does not advocate the owning of such equipment by the railroads in this Country. With regard to handling l. c. l. shipments and parcel post and express shipments in the same individual carriers, Chairman Davis suggested that an obstacle probably would be met with, in that the railroads are required to make express shipments in baggage cars. They cannot truck the goods from the city to a suburb or an outlying town. They must actually put it into a baggage car, transport it and rehandle it at the other end. Replying to a question with regard to the use of unit containers Mr. Horner suggested that these were only practicable for regulated loads, in other words, when the same quantity of goods is shipped in both directions between the consignee and the consignor. It is not practicable if the goods must be picked up at 15 or 20 different points in one locality, and delivered at 15 or 20 other points in the second locality. In order that the container plan may be used to advantage, there must be the closest cooperation and coordination between the shippers, the railroads and the cartage interests. Unit containers would be of especial advantage when goods must be transferred several times on the way; in such cases it would avoid their being handled piece by piece.

A. J. Slade stated that actually to secure a real and sensible improvement in the present chaotic and extravagant methods, the various interests concerned in efficient transportation must be brought to a realization that one or the other interest must take the initiative in preparing a definite plan for the coordination of transport operations. In 1912 during a visit to England, he had found that the British store-door delivery system was firmly and permanently established, that in talking with one railroad official, who had just returned from a visit to the United States to investigate the use of motor vehicles by American railroads, this official had been surprised to discover that our railroads had not given the matter especial attention. Mr. Slade attributed this to the fact that the rapid growth of the population in the United States had directed the energies of the railroads toward the extension of their lines in newly settled communities and toward providing for the continually increasing traffic on existing lines; whereas in Europe where increases in the population are not occurring, the railroad companies have had more opportunity to devote their energy toward improving the service. During the last year, while in France, his personal experience had been exactly opposite to that cited by Mr. Horner, in connection with a shipment from Baltimore to New York City, a shipment made from a small town near Nice having been received at his apartment in Paris on a single bill of lading, and the payment of all charges being made when the shipment arrived at its destination.

W. H. Lyford said that high pressure of the industries seems to bring out the importance of real transportation when a shortage of cars and the delays of transportation begin to limit production, that the paramount need of adequate transportation is brought home to the producing industry and that there is a general recognition of the fact that industries and traders generally are interested more in adequate transportation than in cheap transportation. An understanding of the importance of transportation to industry ought to lead to the public's approval of any measures that would lead to an increase in the efficiency of the transportation system and impress the public with the fact that the credit of a transportation system must be assured and maintained in order that the railroads may add to their facilities measurably with the increase of the traffic. He said that he approved all Mr. Horner's views, but that Mr. Horner in describing how each railroad company in Great Britain has its own cartage system in each terminal area and that the collection and delivery is contracted for and performed by the railroad company, had left out two important facts: first, that such cartage service is paid for by the traders and is a separate charge that generally is made part of an inclusive rate for complete transportation from the store-doors of the shippers to the store-doors of the consignees, but that need not be paid if the trader prefers to perform his own cartage service. Although the use by the trader of the collection and delivery service operated by the railroads in Great Britain is voluntary, the organized cartage service operated by the railroads is cheaper than such service could be performed by the traders, and therefore it is accepted generally by them and insisted upon; in the second place, he would seriously oppose any attempt by American railroads to carry on a cartage service. The operation of motor trucks is a comparatively new industry. During the short period of about 13 years it has developed experience and efficiency, but American railroad organizations have no knowledge and no experience in this field. On the other hand, British railroads began collection and delivery more than 50 years ago, and they have developed within their organization separate departments under cartage managers, that have produced experts and high efficiency. His experience with railroad organizations and their activities have satisfied him that when a railroad organization undertakes an outside activity the result is a failure. The railroad finds itself unable to compete with those organizations that have devoted their entire attention to those activities and have had the experience that the railroads lack. Three London railroads in 1912 determined that one cartage organization could serve all three of them more economically and efficiently than they were being served by three separate companies. Accordingly, they selected a cartage expert and turned over to him all their cartage facilities in London, allowing him to perfect his own organization; and immediately there was an increase in efficiency, in economy and in service. A further development covering all the railroads in London was interfered with by the war and has not yet become effective. As the collection and delivery service must be paid for by the traders it should be made as efficient and as economical as possible and the highest economy and efficiency can be obtained best by a single organization in each railroad terminal area. It must be wholly impartial in its treatment of the various traders and the different railroads, and therefore should not be controlled by any railroad or by all the railroads, but should be an independent organization working in the closest harmony with the railroads. Without full cooperation with the railroads the collection and delivery of goods will not produce the one great result of which it is capable, namely, the free movement of freight through railroad terminals and the prevention of congestion that limits the volume of railroad traffic. To avoid congestion of the station platform there

F. C. Horner Major Brainerd Taylor

AUTHORS OF TWO OF THE PAPERS PRESENTED AT THE SECOND MOTOR-TRUCK SESSION

must be a line of vehicles or containers to which all freight from the long line of freight cars can be trucked directly, and those containers must remain until the train is unloaded, unless they have received their full load in the meantime. The British meet the situation by lining up their lorries at the station platform but release the horses and the drivers while the lorries are standing to be loaded or unloaded. American efficiency would not allow slow-moving horse vehicles to be used for this service, for in all large cities the horse-drawn vehicle adds unreasonably to street congestion and the automotive vehicle is absolutely necessary. A motor truck is economical only when it is kept moving; therefore, in a majority of cases, the ordinary motor truck is not economical for station service. This difficulty has been solved by designing, building and operating a demountable body and a semi-trailer or trailer. Walter White and his lieutenant, B. F. Fitch, are entitled to the credit of proving the efficiency of the motor truck with demountable bodies for railroad station service. In Cincinnati the use of 15 chassis and 225 demountable bodies has displaced thousands of freight cars and released them for line hauls. The efficiency and economy of the semi-trailer for railroad station service has also been demonstrated by Mr. Childress between East St. Louis and the stations and traders in St. Louis. A comparatively inexpensive demountable body, or semi-trailer, can stand this delay at the railroad station, and the expensive tractor and driver can be kept moving.

There is also great need for a system of cartage control. At Cincinnati where the system has been developed to the highest degree, the despatcher is in constant touch with his drivers and moves them exactly as a train despatcher controls the trains on each division. Whenever a truck body is completely loaded the despatcher sends the most available driver to remove it and replaces it with an empty body or an outbound load. One British station was used three different times in 24 hr. for three entirely separate operations, whereas in America three different stations are required for the same service and to handle the same volume of freight. The British freight service, supplemented by adequate cartage, makes unnecessary the express company and the heavy parcel post, and is superior to our present express and parcel post service. All freight collected in London, Manchester or Glasgow before 5.00 p. m. will be delivered to the consignee at his store-door before noon of the following day at any destination within 200 miles of the shipping point. The merchandise freight service of American railroads is even more efficient than those of the British railroads but the difficulty is that there is no adequate delivery service to transfer the freight from the car to the consignee. Merchandise that is delivered before 5.00 p. m. at a freight station in any large American city and is destined for points on the main lines of railroads within 250 miles will be standing at the destination ready to be unloaded early the following morning, but after the freight arrives the agent must telephone or send a postal card to the consignee, who is allowed 48 hr. from the following morning within which to take delivery of the freight. In Great Britain the freight would be delivered to the door of the consignee before the postal card could reach him. In Mr. Lyford's judgment there is no way in which the adequacy, efficiency, and economy of transportation can be increased so much and so quickly as by the adoption of such organized collection and delivery service.

Illustrating the economy of money and of time that may be effected by the short haul of the motor truck, Mr. Horner cited an instance, in which this service has recently been put into operation by the Pennsylvania Railroad. The railroad has been taking care of a certain section of the Eastern Shore of Maryland by shipping goods to Wilmington, Del., then over the New York, Philadelphia and Norfolk Railroad to the Eastern Shore. This took anywhere from 2 to 3 days, sometimes 4 days. The railroad has now worked out a system whereby they load this traffic on a boat at night at Baltimore, take it down to Cambridge, Md., unload it there and distribute it to the various towns by motor truck, delivering it the following day, much of it by 4 o'clock in the afternoon. The trucks that make the delivery pick up loads, bring them in, and the reverse movement takes place to Baltimore and other points. Mr. Horner called attention to the fact that the railroads are concerned just now with the addition of cars and locomotives to their equipment, but that it is not lack of equipment of the railroads that is causing the delay but the congestion at the terminals that act like the neck of a bottle. If the terminals could be cleared the number of cars and locomotives needed to handle the same volume of traffic could be reduced and the cost also would be less. In England although the railways cart 80 per cent of the l. c. l. traffic themselves, the charges are arranged so that they include both the rail charge and the cartage at both ends.

If the trader takes it upon himself to collect the traffic and bring it to the station or to deliver the traffic from the station, he asks for a rebate. Under the Railroad Act of 1921 this system will be done away with. The charges must be divided into the straight rail charge and the cartage charge, given separately. If the trader thinks that he can make the collection or delivery more economically than the cartage charge by the railroad he may do so.

Mr. Horner said that in the city of London horses are largely used, that the streets are so narrow and so crooked that it is almost impossible to use motor trucks of any size and that the stations are very close together so that the haul is short and the stops are frequent.

Mr. Galvin speaking from the viewpoint of the Haulers Association said that the trouble was largely because of delay by the shipper and suggested that a committee should investigate some of the troubles with a view to preventing the delay. He expressed the desire of his association to cooperate in the efforts to systematize the delivery of freight in large cities.

H. M. Crane remarked that although certain members of the Society like Mr. Lyford's unqualified statement that the railroads are not interested in extending their transportation beyond their present freight terminals it seemed to him to be very desirable that there should be a complete transportation service to the door by one organization; that if automotive engineers would work out a trucking system that would be certain and economical in operation, the railroads would undoubtedly be more ready to take it on as part of their own work. He considered the trucking service in many respects very similar to taxicab service but did not think that anyone felt that the railroads should handle their own taxicab service.

Mr. Lyford replied that he did not wish it understood that the railroads objected to having an organization that would perform complete transportation from the store-door of the shipper to the store-door of the consignee; that the advantages of parcel post service and of express service were obvious; that the immense growth of both compared with that of the freight service was positive proof that shippers realize the advantages of a collection and delivery service and of a complete transportation contract. He hoped that such a system would be evolved but he did not think it would be possible to have it accepted by the people of the Country if it were put forward by the railroad companies. He said that he had emphasized the profitable features of this service to make it attractive so that some one else would take care of it. He believes that in this Country there should be a great nation-wide organization that would undertake to perform complete transportation from every shipper, at least those in communities of more than 2000 to 3000 people, to every consignee in a similar community, would contract for it all the way, furnish the cartage at each end, pay the railroad company its regular rate for the rail part of the transportation and cooperate closely with the railroad company so that the greatest possible amount of freight might be passed through the terminals.

Replying to Mr. Horner's question as to whether it would not be to the advantage of the railroads to furnish cartage service at cost if it would serve to move traffic faster through the terminals and reduce the cost of handling, Mr. Lyford said that as an economic problem he believed that it would be advantageous to do so, but that whenever the railroads had furnished additional facilities they were forced to absorb the cost, and that it would be absolutely impossible to persuade American railway managers to undertake such service.

In closing the discussion, Mr. Horner noted that the English railroads maintained their cartage service because of its advertising value. The competition between the various railroads in England is very keen, and one of the greatest advertising agencies that they have is these vehicles scattered through the streets of the cities with every driver soliciting traffic for his own railroad. He believes that, in analyzing the problem from all sides, this feature should not be lost sight of.

STREET RAILWAY AND BUS OPERATION

Electric Railway Executive Explains How One Must Supplement the Other

The Friday morning professional session at the Cleveland Transportation Meeting was devoted to the motorbus. The Society was fortunate in having the principal talk at this session given by C. D. Emmons, who is president of the American Electric Railway Association and able to speak authoritatively for the street railway men of the Country. Mr. Emmons is also president of the United Railways & Electric Co. of Baltimore, in which capacity he directs the coordinated operation of electric surface-cars, gasoline motorbuses and electric trackless-trolley buses. Mr. Emmons centered his remarks upon the coordination of motorbus and motor-truck service with transportation upon rails. His paper is printed in full on p. 433 of this issue of THE JOURNAL.

President Alden expressed the opinion that population, factories, recreation centers and stores should be scattered instead of concentrated or centralized as they are at present. He deplored the common practice of drawing building activity to the route of each new artery of transportation immediately its route is set. This often leads to the overtaxing of the passenger capacity of the new line, even before it is placed in operation. Mr. Alden is a member of the Rapid Transit Commission of Detroit and he said that that body intended to break up the concentration of population in that city if it was at all practical. The big transportation industries have not all had an equitable deal from the public in the past, but we are entering a 10-year period when the public utilities and the railroads will receive fair treatment and the automotive industry must be in accord with this new attitude.

FIFTH AVENUE BUS EXPERIENCE

An informative and well prepared discussion of Mr. Emmons' paper was read by R. E. Fielder of the Fifth Avenue Coach Co. He took issue with the statements in the paper relating to the ability of the motorbus to handle mass transportation. The estimate of bus headway and passengers carried on Fifth Avenue as based on the count taken by Mr. Emmons' representatives, did not take weather conditions into consideration. He selected a day in the month of March when climatic changes are problematic and bus headway is governed accordingly. Allowance must also be made for the fact that no standees are permitted in Fifth Avenue bus travel and this reduces bus capacity when it is compared with the street car, where standees are carried in large numbers. Mr. Fielder cited the following figures as being averages over extended periods of time: during the morning rush, an average of 183 buses operated south on Fifth Avenue during 1 hr. at the point where Mr. Emmons took his observations, the headway being 19.6 sec. This is equivalent to transporting 9333 persons in an hour. The Fifth Avenue buses carried 52,000,000 passengers in 1922; on the high-record day recently, they carried 269,509 passengers and this was reduced the day following to 180,000 persons because of rainy weather. This illustrates why it is unfair for Mr. Emmons to base his figures on a count taken on a particular day in March without regard to traffic and weather conditions.

ADVANTAGES OF MOTORBUSES

Mr. Fielder read his version of the 14 points of bus superiority. The foremost of these is undoubtedly the flexibility of the unit, since it does not need rails on which to operate and can be switched from thoroughfare to thoroughfare at will; also, because it loads and unloads at the curb, allowing other traffic to pass at its left; there is no tie-up of traffic as in the case of the street car, that is usually in the middle of the street and stops all traffic while it takes on or discharges passengers. The motorbus is independent of a central powerhouse. Should any mechanical breakdown occur, the disabled unit can be placed to one side without tieing up the whole system. Elevated structures and overhead wires are unsightly and the motorbus does away with them. Streets are not being torn up continually for laying or replacing car-tracks.

Municipalities will find it to their advantage to franchise properly organized and reputable corporations to render bus service rather than to hand out the right promiscuously to fly-by-night companies and jitneys, whose sole object is to give service only at rush hours and not throughout the day and the night. Mr. Fielder said that the Fifth Avenue company pays taxes that are proportionately as heavy per unit as those of any street railway; all taxes, city, state and federal, amount to $2,000 per vehicle operated. The Fifth Avenue Coach Co. has built and discarded 19 types of bus in the past 8 years. In the next few years we shall witness a transformation in the bus industry, for it is still in its infancy; many innovations will be introduced that will place the motorbus on a par with the electric railway and the steam road. All three systems will work side by side in bringing this about and each in the end will render a service that is indispensable.

ELECTRIC RAILWAYS SHOULD GRASP BUS OPPORTUNITY

W. P. Kennedy presented a very able discussion that brought out some novel ideas. It was his opinion that the railways should not assume that they are under oppression due to the advent of the motorbus; rather, they are to look upon this event as the forerunner of a greater opportunity than they have ever had in their experience. Instead of dwelling upon the temporary irritation, the motorbus should be studied as a magnificent opportunity for expansion, primarily on the part of the railway industry and secondarily, for the automotive industry. The street railway is in difficulty largely because it has been a non-competitive business; its executives have assumed that nothing would ever displace them. They have gone ahead without meeting demands for the kind of economy that has been forced upon the automotive industry due to competitive conditions within that industry. They proceeded in the direction of building heavier and more luxurious cars and have developed structures, in some instances, that weigh about 80,000 lb. They are now being forced to consider vehicles of the lightest weight to carry the greatest load and have perfected cars weighing 28,000 lb. that perform the same service as the heavy units with a very marked reduction in operating expense.

The motorbus and the motor truck represent a golden opportunity for the street railways to free themselves of many of their present incumbrances. They have been tied to the track and made the mark of all legislative restrictions; the flexible vehicle in the form of the motorbus offers them the way out of many of their difficulties: It was not Mr. Kennedy's opinion that the street railways could entirely rid themselves of all their present incumbrances, but they can have a condition of operation paralleling competitive operations. It will be very foolish for the street railways to assume the attitude of forcing the very restrictions that

have retarded the expansion of the street railway industry on the motorbus industry, only to find that the boomerang will return to themselves eventually.

Can Street Railways Handle Freight?

The railroads are suffering from a want of urban transportation facilities and seek a solution of the store-door delivery problem; the street railways are suffering from an inadequate return upon their investment, yet the street railways possess splendid personnel and facilities for performing additional transportation activity. Mr. Kennedy asked why it is not possible to have an alignment of these two means of transportation with advantage to both and to the public. He believed that it would not be difficult to build an automobile that could operate on a trolley system with its relatively cheap source of power, and at the same time operate independently with gasoline power. The application of such a vehicle would immediately give the street railway companies an opportunity to restore lines that had been abandoned because the district traversed had changed from a residential to a commercial character.

The fact should stand out forcibly that the street railway industry is dependent upon the automotive industry for the solution of its equipment problem in this new extension of its service. The automotive industry, by close counsel and cooperation with the railway industry, must provide equipment to meet the new service requirements. Such expansion presents a great opportunity to the automotive industry because the railways represent prospective customers who are intelligent operators and purchasers requiring products that must be more or less standardized. The automotive engineer also has a great opportunity placed before him in the design of flexible vehicles of a new character beyond the capacity of those now furnished.

F. C. Horner voiced the opinion that ruinous and wasteful competition between the street railway and the motorbus companies must stop. If we intend to solve our transit problems satisfactorily, and with some degree of permanency, it must be done through cooperation and coordination. The trolley car line is the backbone of the present transportation system, but there was some question in Mr. Horner's mind whether this would be the case in the future. The trolley car as it is being operated in very many of our cities today is one of the biggest influences in retarding the speed of street traffic. To speed up street traffic, congestion must be reduced and accomplishment of this will react against the trolley car. R. E. Plimpton of *Bus Transportation* said that his contact with the street railway operators had shown him that they were in the field for a well-tried design of bus that could be bought complete. They do not want to rebuild or reproportion the unit after it is purchased; nor do they want to purchase and install additional equipment. Mr. Plimpton felt that it is up to the automotive engineer to develop real buses designed for the service of the street railways. The latest figures that he had available indicated that the number of buses operated by street railways would be doubled during the current year. The knowledge that the street railways are rapidly acquiring should be of great help to the automotive engineers in solving such pressing problems as the design of brakes and transmissions for motorbus service. Bodies are also due for improvement in the way of lighter weight combined with greater strength. Most of the electric railways maintain complete shop equipment to handle renewals and make repairs; most of them have well equipped wood-working and painting shops, and many of them are equipped to rebuild their equipment entirely. This means that they will be in possession of very valuable maintenance experience that can be passed on to the automotive engineer.

Mr. Plimton brought out the point that the electric street railways are able to determine their costs of operation very accurately. He felt that their entrance into the bus operating field would mean that reliable cost statistics would be compiled and published on the operating expense of motor vehicles. It is especially important that those interested in the extension and development of motorbus service keep an eye on legislative matters. Many of the laws now being passed are so inflexible in their requirements that they are impracticable and should never be passed.

F. E. Sanborn, secretary of the Cleveland Akron Bus Line, said that the foremost problem before the bus operators in Ohio has been the destructive legislation set up by some municipalities in opposition to the operators of motorbuses. In every instance where he had been able to ascertain the source of this legislation, he found it had been brought about or induced by electric railways who wanted to put the bus out of business. He believed that the electric railways were wrongfully blaming the motorbus for their troubles in many instances where this was unjustified. In his own instance, the electric railway between Akron and Cleveland was in a stronger position financially than other lines in Ohio that were not paralleled by motorbus lines. It was his belief that motorbuses do not draw the large part of their patrons from the trolleys; they are people who have not been using any means of public transportation. Two of the largest problems facing the motorbus operator are the matter of proper financing and the setting up of an efficient organization. Mr. Sanborn favored the continuance of bus operation by the pioneer bus operators and not turning the field over to the electric railways. The electric lines are all heavily in debt for their present equipment and if they start the operation of the bus lines and abandon their present plants, the bus system will be called upon to bear this financial burden of liquidation.

Mr. Emmons replied to Mr. Sanborn by saying that some of the electric railways had been backward about bus development but that he had advocated the uses of buses for many years and had pioneered their operation by an electric traction company in parallel with its trolley cars. He was not sure that he could see the fairness in allowing a bus operator to parallel an interurban line in a competitive way, using a rural highway that the traction company had helped to build through its taxes, and taking from that traction company the best portion of its business without being subject to service, fare or tax regulations that placed the bus in at least the same status as the electric railway.

DEPARTMENT-STORE PARCEL DELIVERY

Phases of the Distribution of Light-Weight Packages Usually Overlooked

Harold B. Wess, of R. H. Macy & Co., Inc., New York City, in his paper, which is printed on p. 465, described the last contact that is had with a customer in the delivering of parcels. Mr. Wess said that he was interested in the reasons that had been given by a previous speaker for the use of horses in London. A salesman had recently talked to him about the speed of making delivery, not realizing that in the department-store business it was not the speed with which the vehicles traveled but the length of the stops that was most important; that the vehicle stops most of the time and that when it moves, it moves only for a minute or two. He said that the horse might eventually be done away with but that such a contingency would not happen until engineers had perfected a motor vehicle sufficiently light to operate as cheaply as that drawn by a horse. Replying to questions concerning the average time per stop, the average weight per delivery, the average miles per hour, and the like, Mr. Wess stated that an electric vehicle would probably cover 20 to 25 miles in a day of 8 hr. but that mileage enters only when the distance is from 30 to 50 miles per day in the suburbs. The length of the stops varies from ½ to 2 min. The question of weight is not essential as the articles delivered are mostly parcels.

Special bulk delivery is used for groceries and house furnishings. Probably the heaviest article in parcel delivery is a can of vegetables. The plan of rating the parcels to be distributed by department stores by weight and size has been outlined and the stores have been urged to adopt the classification. Two-ton trucks have been used but this capacity is excessive. What the stores need is a truck as light as can be built.

In closing the discussion Chairman Davis likened the motor-truck for department-store delivery to an illiterate immigrant arriving in this Country, who possesses potential usefulness, rugged strength and ability but who needs considerable training, direction and control before results can be attained that will amount to anything.

Major Brainerd Taylor of the Quartermaster Corps described the Military and Commercial Highway-Transport, his paper being printed in full in this issue of THE JOURNAL, commencing on p. 413. The brief discussion that followed was participated in by Chairman Davis, A. J. Scaife, B. B. Bachman, Col. E. S. Stayer, Mr. Krum and Major Taylor.

TAXICAB CONSTRUCTION AND OPERATION

Strong Bodies Needed—Large Cross-Section Tires and Four-Wheel Brakes Desirable

The Friday afternoon session, at which A. J. Scaife presided, was devoted to the presentation and discussion of papers on taxicab bodies and the construction, maintenance and operation of taxicabs.

H. G. Bersie, in submitting his paper on taxicab body construction, said that there were on Jan. 1 of this year at least 110,000 taxicabs in operation, and that these run 50,000 miles

H. G. Bersie R. H. Croninger

SPEAKERS AT THE TAXICAB SESSION

per year each on the average. He pointed out that the quality of the body depends upon its skeleton, the main sills carrying the weight of the whole body as well as that of the passengers. He expressed the opinion that a taxicab body should be 50 per cent heavier than a passenger-car body of the same size. The body of the former type is reinforced with iron over the wheel housings; a very substantial rear door is necessary. Mr. Bersie gave many interesting facts and figures in his paper, which is included in full in this issue of THE JOURNAL.

Paul H. Geyser, of the Yellow Cab Mfg. Co., who was scheduled to present a paper on taxicab construction, maintenance and operation, was unable to appear. R. Harry Croninger, of the same company, presented the paper with interpolated discussion that was keenly listened to. Mr. Croninger said that his company is using a brake-lining which gives 40,000 miles of service. On a rainy day as many as 10,000 telephone calls are received in one hour by the company, which has 500 miles of its own telephone wires and the largest commercial switchboard in the world. The company operates 1700 taxicabs in Chicago. Among the many interesting maintenance items is the washing and fumigating of a cab in 40 min. The practice of the company is not to drain the engine crankcase oil periodically, but to make "finger" tests of the actual oil in the crankcase frequently to judge of its viscosity.

Perhaps the principal point Mr. Croninger made was that designing, operating and maintaining a taxicab are essentially different from corresponding procedures in connection with other automotive vehicles. There is a 400-lb. frame in the larger cab, which weighs 4000 lb. and carries two people 90 per cent of the time. A frame of the same weight is used in the 3200-lb. cab. Ten-gage steel is used in the running-boards and 14-gage in the fenders.

Mr. Croninger said that the best gasoline economy is obtained with 5-in. tires, the use of these resulting in a reduced variation of the vehicle speed in going over tracks and cobblestones. He expressed the opinion that it is very desirable that a successful four-wheel brake system for taxicabs be developed. He said that there is much advantage in using a rational size of "big-diameter" tire, a test having shown that a cab skids less with tires of 7-in. cross-section.

Of course, it is essential that no feature of design enter into the construction of a cab that would tend to interrupt its continual operation. The accessible location of all bolts and nuts and the ease and rapidity with which units can be exchanged are as important as the character of the assembly units themselves. In designing a cab serious consideration must be given to what it means to an operator to remove a radiator or front cross-member and what this represents in actual time for disassembling when this requirement is applied to every other point about the cab. Accessibility is as important as dependability. In the practice of the Chicago company 20 min. is allowed for replacing a spring and 40 min. for removing and 50 min. for reinstalling an engine.

In 1922 the Chicago Yellow Cab Co. employed 3200 drivers to operate its 1700 cabs. The passengers carried numbered over 19,000,000, the distance they were carried being over 67,000,000 miles. Approximately 51,000 passengers were carried every day in the year, or 32 passengers per day per cab. The company maintains 10 combined service-stations and garages in Chicago. Eighty per cent of the entire equipment of the company operates 20 hr. each day, in two shifts.

The driver-personnel of the company is of a very high standard, the expense of employing and training a driver being about $200. Many advantages are accorded the men, including the maintenance of a benefit association. The company assists them in the purchase of its stock; about 35 per cent of the stock is owned by employes.

The modern cab, of course, plays an important part in transportation. The operations of the Yellow Cab Mfg. Co. are undoubtedly conspicuous among the most highly developed and remarkable activities of a similar kind in the automotive field. During January of this year its fleet of cabs traveled over 6,500,000 miles. The maintenance cost, including material, labor and burden, was $0.0084 per mile. About one-third of this fleet had traveled over 200,000 miles.

THE RAILROADS AND THE INDUSTRY

Relations Existing Between Them Discussed at Cleveland Transportation Dinner

It is usual to expect an atmosphere of enthusiasm and good fellowship at the dinner meetings of the Society as they occur from time to time, and for those in attendance to anticipate pleasurably the important information that is certain to be conveyed by the speakers, but it is seldom that such expectations and anticipations are realized to any greater extent than was true at the Cleveland Automotive Transportation Dinner held April 26, 1923, in the ballroom of the Hotel Winton and attended by more than 200 members and guests. President H. W. Alden was chairman; he stepped on the gas without hesitation and let the dinner

session into "high" with no clashing of gears by introducing George M. Graham, vice-president of the Chandler Motor Car Co., as one of the best worm-drive toastmasters in the Country.

In his introductory remarks, Mr. Graham spoke of the extent to which transportation had failed to develop until within the past 120 years, and emphasized that automotive engineers are pioneers in a great forward step for transportation, particularly in their attempts to correlate each factor of that transportation with all its other factors. He then introduced Alfred H. Swayne, vice-president of the General Motors Corporation, whose subject was "The Relation of the Automotive Industry to the Railroads," and who spoke, in part, as follows:

> The Chamber of Commerce of the United States invited the National Automobile Chamber of Commerce to send a committee . . . to meet a committee of railroad executives . . . Our committee discussed the question previously and outlined a policy which it would adopt if the discussion turned out to be in regard to the general attitude of the automotive industry toward the railroads. At that meeting Secretary of Commerce Herbert Hoover said that in the judgment of the administration railroad questions would be one of the chief issues in the next campaign and that unless something was done of a constructive nature to improve the transportation situation, we would drift into Government ownership of the railroads. He believed that this would not be for the best interests of the Country and that it was not what the Country wanted. He said that he had suggested this conference with a view toward seeing what could be done along constructive lines to improve conditions.
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> We then heard from the railroad executives representing 80 per cent of the mileage of the railroads in the United States. We listened to a lengthy discussion of the troubles of the railroads, of the difficulties of regulation and Government interference, and to the long history of legislation hostile to the railroads; but nothing of a constructive nature was brought out in going over a lot of old ground with which we were all more or less familiar, and we were told it was practically impossible for the railroads to get new capital under existing conditions . . .
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> When our turn came to discuss the matter, we told them very frankly we admitted all they said and recognized the importance of all their arguments, but that we were shippers and were vitally interested in getting transportation; that we had plants and dealers' organizations all over this Country; and that, without a steady flow of raw materials into our factories and finished product from them, we could not succeed in our business. We said we recognized that the railroads must expand their facilities to take care of our traffic, and realized that this could not be done without adequate capital. Also, that we knew they could not get that capital unless they had rates that would give a good return, and that this meant a return sufficiently attractive to induce new capital to enter the business to expand the railroads so as to take care of the Country's growth. We tried to make clear to them that we believed the interests of the automotive industry and those of the railroads lay along the line of cooperation and not opposition. . . .
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> We pointed out that we were one of the large customers of the railroads, that we should be good friends and that this would be to our mutual advantage if we worked together instead of against each other. We then said that we felt that a constructive program was necessary, and that we looked to the railroad men to develop this program. They knew the business and we did not; they had invested generations of experience in it, and they could hardly expect us to develop the remedy. The railroad representatives told us that, as shippers, we ought to take an interest in the problem. Our answer was: "What shall we do? We do take an interest. What do you want us to do of a constructive nature?"
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> We pointed out to them that one of the criticisms which seemed to be well founded was that they had the reputation of not being able to sink their differences and work together. We told them that if they would develop a program and the railroads and the automotive industry could agree upon it and would support it, that we would use our manufacturing and our dealers' organizations all over this Country to develop a sound public opinion, behind that program, and to endeavor to put it through Congress next winter. . . . Finally, Mr. Hoover said that he approved the attitude of our committee and thought that it was constructive. A resolution was proposed that the Chamber of Commerce of the United States appoint a committee which should make a thorough study of the transportation questions affecting the railroads, highways and waterways; and that on this committee should be represented the railroads, industry, agriculture and labor. That committee was appointed, and is now at work.
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> In the automotive industry, . . . we cannot succeed in our business and manufacture and distribute economically without the best of railroad transportation. . . . We can either pay for it in support of private ownership and give the railroads a chance to make reasonable returns on their capital, or we can let them drift into Government ownership, get poor service and pay for it in high taxes. . . . You will find that our interest lies in the support of private ownership of the railroads, in giving to them sufficient backing and help to develop a machine that can do our business economically and efficiently. . . . I am confident that the administration has three main points in view. First, to develop some railroad consolidations which it thinks will be in the interest of economy and efficiency. Second, to have a scientific revision of rates. . . . Third, the consolidation of the Railroad Labor Board and the Interstate Commerce Commission. It feels, and I think rightly so, that one body should be responsible for both income and outgo. . . .
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> Regarding railroad capital, it is a well understood principle of finance that certain relations must be maintained between junior securities and senior securities. By senior securities, I mean bonded debt and preference shares. . . . The proper proportions between the two must not be allowed to get out of line.
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> Since 1915 the railroads of this country have been unable to issue any common stock for capital purposes. It is evident that the railroads are spending money now for equipment and for expansion of various kinds, but they are simply mortgaging the surpluses that they built up before this state of affairs existed. They will come to the end of that before long. In the opinion of the best bankers, they have nearly reached the end now. Then the Country will find that it cannot get increased railroad transportation. The public will become impatient at that state of affairs and there will be only one credit available, that of the Government, and there will be pressure brought to bear to put the railroads into the hands of the Government, which I think would be greatly to our disadvantage. . . . When the Chamber of Commerce of the United States has developed this plan and introduces it to the public and to Congress, I hope automotive engineers will support it and do all within their power to develop a sound public opinion behind it. We should do this because it will be good business to do it; we should do this because it will be good citizenship.

The Automotive and the Railroad Interests

The need for the correlation of the automotive and the railroad interests was voiced in specific manner by W. J. L. Banham, general traffic manager of the Otis Elevator Co. and president of the Associated Traffic Clubs of America, the next speaker.

Stating that the lack of transportation is seriously impeding the production of the country and that, unless a condition can be created whereby it will be possible to move a substantially increased tonnage by the more intensive use of our present facilities, the present unsatisfactory situation will continue and the public will be required to pay high freight rates and receive unsatisfactory service in return, Mr. Banham reviewed present transportation impediments, inclusive of the congestion at railroad terminals and the restricted use of motor trucks, as a preface to discussing how these obstacles can be removed and how better coordination between the two transportation systems can be accomplished. To this end, an avoidance of long distance competition between motor trucks and railroads appears reasonable, and it seems that the activities of the motor truck should be confined largely to the movement of freight within the railroad-terminal area, or adjacent thereto.

To speed up the movement of freight passing through railroad terminals, it will be necessary for the carriers and the shippers to agree upon and develop a system of store-door delivery and collection service that would secure the more intensive use of the present terminals. What is needed at the present time is a much closer cooperation between the shippers and receivers of freight and the rail carriers than has existed hitherto.

In enlarging upon his subject, Mr. Banham discussed the prompt removal of freight from terminals, citing Canadian practice in some detail, and stated his belief that the motor truck and the highways should be used for the handling of short-haul freight covering distances up to 25 miles or distances to be agreed upon by the trucking and the railroad interests. Also, that motor trucks should serve as feeders for the railroads, acting as their agents and with their duties and responsibilities defined clearly by tariff regulations issued with the approval of the State and Federal Commissions.

The movement of less-than-carload freight between the carriers' sub-stations and main stations is also an important problem, and this was treated by Mr. Banham together with the so-called "trap-car" freight-service, believed by freight agents to delay less-than-carload freight seriously. He stated further that the proper understanding of the "field" of the various transportation agencies is vital, but in determining this field each form of transportation should bear its proper responsibilities and charges; no one class of carriers should be subsidized by the Federal Government or by the States to the disadvantage of other competing agencies; only by mutual understanding of the proper relationships can the good of the public as a whole be advanced; and that the encouragement of active and forced competition would, in the end, be destructive.

Present Status of the Railroads

The final address was made by Robert S. Binkerd, vice-chairman of the Committee on Public Relations of the Eastern Railroads, who recounted the efforts of railroad interests, since 1920, to find a sound harmonious transportation policy. He rehearsed the difficulties under which railroads have operated during this period, stating the big railroad problem to be whether the people of the United States will support a constructive policy toward the railroads that will permit them, as economic agents, to supply the facilities and service demanded for the welfare of the country.

Quoting statistics of development and the disadvantageous features of railroad operation under Federal control, the growth and improvement of service and equipment since private ownership again obtained were enlarged upon by Mr. Binkerd at some length. In conclusion, he stated that by Oct. 1, 1923, the railroads will be in better condition than before the war. They are aiming to increase the average loading of all freight cars to 30 tons and the average daily movement of all freight cars to 30 miles. By these higher levels of transportation, they expect to handle this year's great volume of traffic smoothly and efficiently. The railroads are forging ahead regardless of an income that is still inadequate and oblivious of political attacks, and are placing their reliance on the sense of fair play of the American people.

TRACTOR DEFECTS SUMMARIZED

Large Audience Hears Professor Sjogren's Report and Paper by C. M. Eason

The annual Tractor Meeting of the Society in Chicago on April 19 proved to be one of the most successful meetings ever staged in the farm power field. Over 100 representative tractor engineers and builders were in attendance; every one of the principal companies was represented, in some cases by three and four men. It was the consensus of opinion that the meeting had resulted in an excellent cooperative interchange of experience that would be of real value to all who attended.

Two technical sessions and a luncheon constituted the program. The morning session was addressed by Prof. O. W. Sjogren of the University of Nebraska. He presented an extremely valuable and informative paper that embodied an analysis of tractor-test data accumulated during 2 years of testing for the State at the University. Constructive criticism of tractor design, performance and serviceability formed one of the most interesting parts of the paper. The following paragraphs give some of the more important points brought out in the paper itself, and in the discussion that followed its presentation.

One of the outstanding discrepancies in the tractor field is the lack of an accepted standard method of rating, both in the belt and at the drawbar. In several cases, tractors of different makes using the same kind and size of engine have been given ratings of wide variation. Four tractors of different make equipped with identical engines are rated from 30 hp. at 900 r.p.m. to 35 hp. at 850 r.p.m., an increase of 16 per cent in the power rating with a 5½-per cent drop in the speed. In another case, the tractors are rated at 20 and 25 hp. respectively at exactly the same speed, a difference of 25 per cent. These cases indicate the existence of a condition that should be corrected. A standard method of rating, conscientiously observed, would provide a direct means of comparing tractor power. It would tend to instill greater confidence in the tractor industry on the part of prospective users. There should also be an accepted standard for belt speeds to avoid the present confusion. Wide limits may be desirable when a standard is first proposed, but it is time that one or two definite belt speeds be chosen and all machines equipped with pulleys to provide one of these speeds at its rated number of revolutions per minute.

Weight Distribution and Tractive Efficiency

One might assume that the very light tractors would have less weight per drawbar horsepower than the heavier ones. Professor Sjogren's data indicate, however, that the tractors having a total weight of about 4500 lb. have less weight per drawbar horsepower than either or the lighter or heavier ones. The general trend of the relation of total engine weight and engine weight per brake horsepower, indicates that the weight per horsepower increases as the total engine weight increases. Tractive efficiency seems to decline with an increase in the total weight beyond 4500 lb. With the wheel tractor, the tractive efficiency tends to become lower as the total weight per drawbar horsepower increases. Drive-wheel slippage decreases slightly as the total tractor weight increases.

A great variation was found in the amount of fuel required per horsepower-hour for the tractors tested in Nebraska. A variation was noted of 138 per cent, from the

lowest to the highest, on the belt test; and 181 per cent, from lowest to highest, on the drawbar test. The data reveal that the lowest fuel-consumption is secured with engines having cylinders between 5 and 6 in. in diameter. Engines of the valve-in-head type gave better fuel economy than the L-head type on all operating loads. It was notable that the fuel required on drawbar work was almost double that required on belt work.

Defects in Tractors Tested

Professor Sjogren summarized the principal defects that had been encountered in the Nebraska tests for the purpose of offering constructive criticism leading to the production of better tractors. It was necessary to adjust push-rods on a considerable number of the engines before the tractors could be tested. In many of these cases the power output was increased. There were frequent instances where the valves were not fitted properly at the factory. Belt pulleys of the attachment type gave considerable trouble, probably due to their having a short shaft with only one bearing. Lack of proper clearance between pulley and drive wheel was encountered. This is especially undesirable when the tractor is used on wet ground, the soil filling in on the drive wheel until it rubs against the belt pulley and stalls the engine. Some tractors would not allow the engine to be cranked with the belt on; this is a very bad arrangement. Most of the difficulty with cooling systems seemed to be with the fan and its drive. In twenty-one cases the fan-belt was the offender. Clutches had to be adjusted in many cases. In a few instances the carbureter was replaced with one of different size or make and the power and operation materially improved as a result. There were cases where the power output was increased materially by removing the air-cleaner, indicating that the cleaner was too small. Air-cleaners using water should be designed so that the water supply can be replenished while the engine is under load. This is particularly important when working on the belt.

Many tractors were submitted for test equipped with governors that were practically useless. The governor should maintain speed within 5 per cent either way; there were examples where a variation of 50 per cent in the speed was possible. The most frequent difficulty encountered in the ignition system was errors in timing. Difficulty with the chassis was met only in limited degree; there were some instances of improper lubrication, poor steering-gears, and weak construction evidenced by broken bolts, twisted frames and broken gears.

Suggestions for Improved Design

More attention should be given to the comfort of the driver. He should be seated so that he has a good view of the field ahead of him. The seat should be located so that he will not be directly in the path of the hot air blast from the fan, nor in a position close to exhaust pipes or other heated units. Accessibility should be carried to the utmost degree of convenience for inspection, adjustment and repair. Professor Sjogren made three specific recommendations.

(1) More rigid inspection of parts as well as the finished machine
(2) More rigid tryouts in the field under various conditions before the tractor is finally approved for production
(3) A choice of accessories based on a thorough study of them as related to the particular machine in question

Professor Sjogren's paper was followed by a very active discussion. A. W. Scarratt urged the adoption of some standard method of rating, remarking that differences in transmission did not warrant the extravagant claims made by some companies who used stock engines that were given a lower rating by other and more conservative firms. H. A. Huebotter of Purdue University agreed with Mr. Scarratt, saying that not over 30 per cent of the tractor engines are rated lower than 80 per cent of their maximum belt horsepower. He asked Professor Sjogren what field condition was represented in the test-track soil at the University of Nebraska. Professor Sjogren replied that it was difficult to say. The so-called cinder track was, in reality, only covered with a thin bed of cinders to improve drainage conditions and arrive at a more nearly uniform condition of the soil for testing purposes. He would judge it to approximate a plowed field of medium hardness with fairly compact bottom soil, stubble ground rather than covered with sod.

R. F. Vogt, of the Allis-Chalmers Mfg. Co., read a prepared discussion in which he claimed that the Nebraska test practice of measuring wheel revolutions on only one rear wheel brought an appreciable error into all of the performance calculations, particularly those involving wheel slippage. He submitted examples calculated from Nebraska test data to show that a reasonable difference in the number of revolutions between the two rear wheels would result in the drawing of erroneous conclusions if the revolutions of only one wheel were considered. Professor Sjogren stated that he was convinced that there could not be any great difference between the speed of the two wheels under the test conditions. He had checked this matter closely with electric tachometers that are now a part of the regular test equipment, and the variation was never found to exceed 5 per cent in the extreme cases. Slippage data are now given in the test reports in two ways to avoid a criticism that has been voiced in the past; one column gives the figures based on the diameter of the drive wheel measured at the outer point of the driving lugs; a second column includes these same data based on a diameter taken at the rim of the drive wheels.

Asked regarding fuel consumption, Professor Sjogren said that the tractors burning kerosene used from 0.63 to 1.40 lb. per b. hp-hr. Those using gasoline burned from 0.65 to 1.13 lb. per b. hp-hr. He had not tested any steam or heavy-oil burning tractors but was in a position to test the latter type. There has been a noticeable improvement in the cooling systems of most of the tractors tested in the last year over the earlier models, very few cases of over-heating being observed. C. M. Eason remarked that the matter of wheel slippage was one of the most troublesome problems before the tractor engineer and gave some of his personal experiences in trying to measure it accurately.

General-Purpose Tractors

C. M. Eason gave an interesting talk on the general-purpose type of tractor at the afternoon session, abstracting his paper which, it is expected, will be printed in an early issue of The Journal. He had gathered a very comprehensive set of photographs illustrating a large number of experimental machines designed to displace completely the horse on the farm. These were shown to the members in slide form and each type discussed by the speaker. O. B. Zimmerman read a short contribution in which he outlined some of the development work done on the general-purpose tractor by the International Harvester Co. A. W. Scarratt believed that the all-purpose machine should be built of a size and power to handle two plows. Dent Parrett called attention to the importance of building greater durability into the general-purpose tractor because of the increased number of hours it would be operated. Prof. J. B. Davidson, of the University of Iowa, was of the opinion that corn cultivation formed the most important problem to be solved in any general-purpose tractor since corn acreage forms the major part of the average American farm. Good directional control is essential in corn cultivation; Professor Davidson did not believe line or rope control would prove satisfactory. He favored using

H. O. K. Meister Prof. J. B. Davidson A. W. Scarratt O. B. Zimmerman R. F. Vogt
SOME OF THE MEN WHO WERE RESPONSIBLE FOR THE SUCCESS OF THE TRACTOR MEETING

only two plows with the general-purpose tractor, but recommended that it be arranged to cultivate four rows at a time. O. B. Zimmerman characterized the later types of tractor as the spider type because of their peculiar appearance when built to straddle and be clear of the rows of growing corn.

C. C. Trump did not agree with Mr. Eason when he stated that the production of steam propelled tractors would not show an increase in the future. He remarked that considerable progress had been made in the more efficient design of boilers, fireboxes and engines so that higher efficiencies were now attainable. The steam tractor will burn wood, straw, oil or coal; it can furnish heat, light and power in the winter season. Several firms are now studying the possibility of building steam-propelled tractors of a lighter type than those now in use, taking advantage of all the latest progress made in combustion and steam engineering.

In closing this account of the 1923 Tractor Meeting, acknowledgment is made of the extremely valuable work of H. O. K. Meister, who was responsible for the excellent group of talks and the other meeting arrangements. Appreciation is recorded also of the fine cooperation of the Farm Equipment Manufacturers' Association in arranging the annual meeting of their Tractor Division on the day following the Society meeting, thus increasing the attractiveness of both meetings and resulting in the large and representative attendance.

FARMERS NEED EFFICIENT TRACTORS

American Farm Bureau Federation's President Gives Tractor Engineers Good Advice

The ultimate type of farm tractor that is suited to the needs of the average American farmer has yet to be developed. This is the opinion of O. E. Bradfute, president of the American Farm Bureau Federation, who addressed the Tractor Luncheon in Chicago on April 19. His address, which was given from the farmer's viewpoint, was received enthusiastically by an audience of ninety members and their guests.

Mr. Bradfute believed that the American farmer is more efficient than the farmers of any other country, when he is judged comparatively by the average acreage that is worked by the farmers in each of the great agricultural nations. Since this efficiency is dependent upon his possession of efficient farm machinery, he is always interested in every advance made in the further application of mechanical power to the work of the farm. The cost per acre of producing grain in 1847 was less than it is today in spite of the use of our highly developed farm implements; this is true whether the cost is figured in dollars or in wheat. The increased cost of labor and farm implements apparently has offset the improvement in farm efficiency and the ultimate costs are not reduced. Thus we see that further engineering advancement is important.

It required a number of years to develop a stabilized and universally accepted design of automobile; this will probably be the case with the tractor. Not only is the type to be determined, but there is no agreement at present on the size best suited to the needs of the average farmer. Mr. Bradfute made a plea for the utmost simplicity in any mechanical equipment that is intended to give service in the hands of the farmer. Adjustments must be easy to make and to understand; there must be a higher degree of accessibility than has been evident in the tractors of the past. Standardization must be applied to the simpler parts such as the nuts, bolts, threads, etc., so that the farmer does not need two or three sets of wrenches to adjust his implements, even though they are the product of several different manufacturers.

P. E. Bradfute Finley P. Mount
TWO OF THE SPEAKERS AT THE TRACTOR LUNCHEON

The ultimate type of tractor must be reasonably inexpensive in first cost because the farmer is not in a position to finance the purchase of expensive equipment. It must be made of the general-purpose type so that it can be used for a longer period of time and completely displace the horses on the farm. Mr. Bradfute said that he was unable to use the tractors on his own farm for a longer period than fifty days of each year. The possibility of a fuel shortage must not be neglected in any discussion of the future farm tractor. The farmer is constantly thinking of the possibility of using the waste products of the farm in producing alcohol for power and heating purposes. He is hopeful that electricity will be used eventually as a means of driving farm tools and hauling his farm implements, for this would enable him to make use of waterpower that is available on many farms and is now being wasted.

The purchasing power of the farmer is a matter of concern to all business men; the present tendency of higher prices in labor and machinery is not being accompanied by a relative increase in the prices of farm products; this is resulting in a limitation of the farmer's ability to buy manufactured goods. We are staring that situation in the face today and the prosperity of the implement and vehicle industry will be adversely affected unless this condition is remedied.

ACROSS THE SAHARA DESERT BY MOTOR CAR

André Citroën Received Enthusiastically at Sessions in New York City and Detroit

A special meeting of the Society was held last month in New York City at which M. André Citroën, a member of the Society resident in Paris, France, who is well known as a gear and car maker, gave very interesting and instructive talks on the crossing of the Sahara Desert by automobiles

ANDRÉ CITROEN

of the track-layer type developed by him and his associates. The moving pictures that M. Citroën showed were extremely novel and indicated vividly the little known conditions of the Sahara Desert. This desert, separating Northern and Equatorial Africa, is an enormous territory 1875 miles in length. It contains a few oases where natives live and there are a limited number of military and civil posts. The camel has been the only means of transit used on it until recently, this means of transit taking M. Citroën said more than a year to traverse the desert.

The speaker pointed out that the soil of the desert is the automobile's most deadly enemy; the sand raised by storms is liable to get into and clog the engine. In fact, inasmuch as the soil cannot be adapted to vehicles of the conventional type, vehicles must be adapted to the soil. A type of car capable of traveling safely across sand and pointed rocks, using as little gasoline and as few tires as possible and yet capable of carrying the necessary load, had to be constructed.

A CONTRAST IN METHODS OF TRANSPORTATION IN THE SAHARA DESERT

In 1921 there were constructed in M. Citroën's factory some cars fitted with apparatus designed by M. Kégresse, a French engineer, who was formerly head of the automobile service of the Czar of Russia. This apparatus consisted essentially of introducing between the soil and the friction rollers carrying the chassis a continuous band of reinforced rubber. The front wheels of the vehicle, which are of the ordinary type, carry relatively very little of the load.

In the first expedition to the Sahara there were five 10-hp. cars carrying two men each. In this the journey from Touggourt to Timbuctoo and return, 3750 miles, was made in 34 "marches" taking 44 days. The second expedition, under the command of M. Citroën, consisted of three light cars carrying six people. It covered 1563 miles of the journey from Touggourt to Tadjemount and return in 10 "marches" taking 16 days. Extra supplies of gasoline were, of course, carried on the cars of the expedition, there being supply posts from 600 to 800 miles apart. Room could not be spared on the cars for the carrying of wireless apparatus. The conditions encountered ranged from the burning sand to icy cold nights. Lighter and faster cars were used in the second expedition, these being able to run at twice the speed of those in the first expedition.

In closing, M. Citroën said that, distance existing only because of the time it takes to compass it, the distances across the Sahara have been reduced in the proportion of 30 to 1, the 1875 miles from Touggourt to Timbuctoo in a track-laying automobile being equivalent to about 60 miles on a camel's back. When routes are mapped out and supply service assured, nothing will prevent comfortable traveling in the desert, the magic and majesty of whose sandy plains extend as far as the horizon, changing in color tone at each hour of the day. The track-laying automobile covered 156 miles per day at the rate of nearly 19 m.p.h.

André Citroën addressed an audience of over 1000 people at the meeting of the Detroit Section of the Society on the evening of April 16 in the auditorium of the General Motors Building. His talk was accompanied by motion pictures of the Trans-Sahara expedition undertaken by a caravan of Citroën-Kégresse track-driven cars. M. Citroën predicted that there would be an increasing interest in the small car in the United States because of the economy of operation and greater ease of handling of the smaller and lighter vehicles. He expressed the opinion that the public would appreciate short wheelbase, narrow tread and short turning radius because of the serious traffic congestion on the streets of our larger cities. Gasoline mileages of these smaller vehicles reaches the 40 figure and tire mileages are materially raised also. It is possible to build these smaller cars so that they seat four persons comfortably, yet do not exceed 1800 lb. in weight complete with body. M. Citroën exhibited a taxicab in Detroit that had a narrow tread and seated two people in the rear compartment; he pointed out that taxicabs seldom carry more than two passengers and he believed that the small light car was ideal for this class of service.

LUBRICATION AN EDUCATIONAL PROBLEM

At the New England Section's meeting on April 26, G. A. Round of the Vacuum Oil Co., New York City, discussed lubrication as a problem in the education of the car operator and owner. Mr. Round pointed out the importance of lubrication and showed that a large percentage of lubrication difficulties which reflect alike on car builder, fuel refiner and lubricant manufacturer, could be prevented by the operator, if he were educated along the right lines. The weaknesses of the usual oil recommendations were cited as examples of what should be avoided. Suggestions were also made for the

education of the car-owner to minimize the dilution, carbon, water and sludge-accumulation evils.

Mr. Round presented some very interesting data on the formation of emulsions and the effect of dilution on the lubricant. He also showed photographs from recent tests, proving that some cases of difficult starting in cold weather are due to the freezing of accumulated moisture in the combustion-chamber. In conclusion, Mr. Round described changes in design that would minimize lubrication difficulties and aid in their control.

Two features are scheduled for the next meeting of the New England Section on May 10 at the Hotel Kimball, Springfield, Mass., beginning at 8 o'clock, following a dinner at 6.30 p. m. R. E. Northway, president of the Northway Motors Corporation, will speak on Types of Automobile Spring-Suspension and Materials for Springs. The Department of Commerce film on alloy steel will be shown, to illustrate Mr. Northway's talk.

ELECTRIC TRUCK ADVANTAGES CITED

Engineer Believes Them Superior to Gasoline Vehicles for City Delivery

Claiming that it costs 70 per cent more to haul urban freight by gasoline-propelled trucks than by electric trucks, J. G. Carroll introduced an active discussion of the motor-transport subject at the meeting of the Mid-West Section on April 20. Mr. Carroll, who is chief engineer of the Walker Vehicle Co., read a well-prepared paper on the General Design of Electric Street Trucks and Their Performance in Urban Work. Descriptions were given of the various types of chassis, motor mountings, batteries, controllers and the methods of final drive that are in general use in the electric vehicle as constructed today.

The electric truck is capable of operating 40 to 50 miles on a single charge of the battery. A large department store reports an average daily mileage of 30; the American Railway Express Co. reports an average of 20 miles daily for its electric trucks. It seems safe to assume that a single charge of the battery assures an ample delivery radius for practically any city route. Operating speeds of electric trucks range from 10 m.p.h. for a 5-ton truck to 18 m.p.h. for a ½-ton truck. The gasoline truck has the advantage over the electric truck on the straightaway, but in multi-stop service the disparity disappears and the electric truck is superior because of its ability to accelerate very quickly.

A distinctive advantage of the electric truck is that all of its moving parts are at rest when the truck makes a stop. On the average 30-mile city route and in 8 hr. time, the trucks are in motion only 2½ to 3½ hr., yet the engine of the gasoline truck will be turning over almost continuously through the entire 8-hr. period. The salient characteristics that contribute to the advantages claimed for electric trucks over those propelled by gasoline engines were enumerated as follows by Mr. Carroll:

(1) Substantial construction and elimination of the reciprocating internal-combustion unit practically eliminates road troubles, reduces maintenance expense to a minimum and obviates the need of highly paid mechanics

(2) Minimum vibration, freedom from adjustments and prevention of careless speeding, prolong useful life of the truck

(3) Reliability and uniform driving power throughout the life of the motor which is designed to deliver maximum power to the driving wheels as required

(4) Operation at safe economical speeds due to the inherent characteristics of the series motor, the speed of which decreases automatically with an increase in the load

Robert E. Wilson was elected chairman of the Mid-West Section at the April meeting. Many of the members are familiar with the valuable research work done by Professor Wilson in the study of fuel volatility, crankcase-oil dilution and the theory of lubrication, the results having been presented at past meetings of the Society. Other officers elected were: Taliaferro Milton, vice-chairman; W. J. Buettner, treasurer, and H. O. K. Meister, secretary.

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THE ESSEX AND SUSSEX HOTEL, SPRING LAKE, N. J.

SUMMER MEETING NEXT MONTH

Spring Lake, N. J., An Attractive Resort That Will Appeal to All

The approach of warmer weather and the summer season reminds us that the popular Summer Meeting of the Society will soon be here. One of the attractive hotels that will house the members at this important medley of business and pleasure is illustrated on this page. Hotel facilities will be found equal to those at any previous summer gathering; there will be ample room for everybody and the service and meals are recommended to us as being of the first order. There has been a strong demand from some quarters for the choice of a seashore resort as a meeting location; Spring Lake will surely appeal to this class. The growing popularity

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GOLF AT SPRING LAKE

of the recreational part of the program necessitated the selection of a location where adequate sport facilities could be had. Spring Lake boasts of two 18-hole golf courses, both well kept and sporty enough to try the skill of those who claim to be graduates of the dub class. There is a fine group of tennis courts for the racket wielders and a still water pool will tempt the more talented exemplars of the Australian crawl.

Plans for the professional meetings are not sufficiently advanced to enable an announcement to be made, but the papers and speakers will be equally as valuable as those presented at other Summer Meetings. Topics will be selected for their general interest and urgency. Further progress on the Society's fuel investigations at the Bureau of Standards will be reported. The matter of crankcase-oil dilution will receive attention. The Standards Committee will hold its semi-annual meeting and vote on new and revised standards that are of vital importance to the industry.

The railroads have offered half-fare return concessions to the members who will journey to the Summer Meeting from nearly all of the automotive territory. It has been possible to prepare a schedule for a special all-Pullman train from the Middle West direct to Spring Lake over the Pennsylvania Railroad. This train will be made up of sleepers from Detroit, Cleveland, Chicago, Dayton, Toledo, Indianapolis, St. Louis and intermediate points. They will all be brought together at Pittsburgh and run from there as a single Society of Automotive Engineers train.

Spring Lake can be reached by paved roads from either New York City or Philadelphia. Garage facilities are provided so that members' cars can be properly stored and taken care of during the meeting period. One of the companies in the industry has prepared a special road map that will be mailed to all of the members some time during the month of May.

Application blanks for reservations, schedule of rates, railroad information and all particulars will reach the entire membership with a special issue of the *Meetings Bulletin* about May 5.

CLEVELAND PAINT MEETING

Double Program on Paint Making and the Sales Appeal of Color

After the inspection trip through the Sherwin-Williams Co.'s Cleveland plant on the afternoon of April 10, J. O. Hasson, director of the company's chemical and technical production sales department, addressed a group of Cleveland Section and Cleveland Engineering Society members in the club room of the Sherwin-Williams plant.

Mr. Hasson compared the scientific making of paint to an engineering problem with its many details demanding for solution a complex organization covering the entire world. The Sherwin-Williams organization includes a testing department for raw materials, chemists, formulators and testers, both technical and practical, for the finished product. Raw materials are tested and analyzed before they are turned over to the formulating department where experienced formulators, working on the reports of the testing department and the chemists' analyses, compose the formulas on which the manufacturing department works. Every known surface, metal, wood, paper or what not, is considered as an individual problem, for which a separate formula must be made. The finished product is thoroughly tested as to drying, covering, flowing and color. After these technical tests, the paint or varnish is tried out under the conditions it would meet in actual use.

The problems of the car builder and the demands he makes on paint have changed with the speeding-up of production and the introduction of metal bodies. The paint and varnish manufacturer who maintains a complete and active research department can prescribe the right finish and method of application for a given use, but he is often hampered by competitive price conditions. Mr. Hasson summed up the unique service of the Sherwin-Williams Co. as that of an automotive finish clinic to handle all the ailments of the automotive industry and all other industries that use technical paints and varnishes, a service that is extended even to the consumer of a product with a Sherwin-Williams finish.

After the usual informal Section dinner, the evening session of the Paint Meeting opened at 8 o'clock in the Hotel Winton. Illness prevented the appearance of Edward S. Jordan, president of the Jordan Motor Car Co., who had been scheduled to speak on The Psychology of Paint in the Appeal of the Motor Car. The Section was fortunate in being able to secure Edward Patton of the Franklin Automobile Co. to speak on the same subject.

Mr. Patton reminded his audience that a man will always buy on the appeal to his emotions when he will not buy on the appeal to his will or his mind. It is the emotional appeal every time that will get the sale. The first step in the selling process is to attract attention. That is where perhaps the coloring and painting of cars is an aid, though the car that will attract the most attention is not necessarily the most desirable. In the long run, a thing must have utility value to succeed. The attention value of color has been vividly brought out by the Red Top Taxicab Co. in Cleveland and by the Checker and the Yellow Cab companies all over the country. Color is the thing that keeps them continually before the public. Direct-by-mail advertising has proved that 15 times as many replies can be brought in by the use of color. It is, of course, unlikely that 15 times as many cars could be sold by changing the color, but there is a chance to put certain colors in certain communities. Mr. Patton illustrated his point by citing some of his own selling experiences. A green car would sell in the lumber camp communities of northern New York, but there was no market for a dark blue car. In the towns made up of wealthy conservatives, the standard dark blue was the only choice. There was one exception in Auburn, N. Y., a green car with red wire wheels caught the fancy of an Italian bootlegger. As a rule, towns of from 30,000 to 40,000 insisted on standard colors; but in the smaller towns and the mountain country, the brighter and cruder the colors, the bigger the sales.

Color has been found to have suggestion values. It tells a story and should, therefore, be suited to the product. You would laugh at a Ford painted a bright red, but you would not laugh at a Stutz in the same color. The big maroon sedan has an air of luxury and a dark blue car has a certain air of aristocratic aloofness. Dark green is always restful, but a vivid green is repellant. A wealthy car owner in central New York was obliged to take a $6,000 depreciation on a vivid green car only six months after he bought it. Brown makes a car look heavy whether it is or not. Black is so widely used in the automobile business probably only for its high utility value. It is not attractive in itself and is almost wholly negative in suggestion.

In conclusion, Mr. Patton emphasized the selling value of appearance. If a car has good lines and a bright color, if it is one the buyer will take pleasure in owning and driving and letting people see, its appearance is the biggest factor in the sale.

The next session of the Cleveland Section, on May 18, will be a business meeting at 8 o'clock, followed by an entertainment, after the usual get-together dinner at the Hotel Winton at 6:30 p. m.

ENGINEERING BRAINS IN FLEET OPERATION

Valuable Discussion at Metropolitan Section Meeting Between Fleet Operators

At the April meeting of the Metropolitan Section, E. E. La Schum, general superintendent of motor-vehicle equipment of the American Railway Express Co., gave a very interesting address on the need of engineering skill in truck fleet operation. J. F. Winchester, supervisor of motor equipment of the Standard Oil Co. of New Jersey, in the comprehensive discussion he presented said that the industry is on the verge of important developments tending toward more

Schedule of Sections Meetings

MAY

1—Dayton Section—Fundamental Principles of the Design of Military Airplanes—W. F. Gerhardt
2—Minneapolis Section—Some Experiences in First Breaking Peat Land—J. L. Larson; Electricity in the Motor Vehicle—North East Electric Co. film
3—Indiana Section—Engineering Information from the Race Track—F. S. Duesenberg
4—Washington Section—Highways and Traffic—Major F. S. Besson
10—New England Section—Types of Automobile Spring-Suspension and Materials for Springs—R. E. Northway; The Story of Alloy-Steel—Department of Commerce film
17—Detroit Section—Four-Wheel Brakes—M. Lougheed
17—Metropolitan Section—Steel—Dr. J. A. Mathews; Non-Ferrous Metals—C. H. Landon; The Story of Alloy-Steel—Department of Commerce film
18—Cleveland Section—Business Meeting

economical operation of motor vehicles. F. C. Horner, of the General Motors Corporation, took a leading part in the discussion, asking among other things what is the best way to decide upon what vehicles to standardize.

Mr. La Schum said that during 1922 the American Railway Express Co. handled more than 184,000,000 shipments, the average weight per shipment being about 82 lb. The gross revenue was $294,000,000. The automotive equipment of the company in the United States and Canada is constituted of over 2600 gasoline vehicles, about 1200 electric trucks of the conventional type and over 300 industrial trucks, together with 100 semi-trailers. While only one-third of the vehicles owned by the company are self-propelled, they have a capacity of over 50 per cent of the total load hauled. The horse-drawn vehicles average 12 miles per day; the electric vehicle 20 miles per day; and the gasoline vehicle 30 miles per day.

The speaker stressed his belief that in connection with all important features of motor-truck equipment and operation, careful analysis should be made by competent engineers. He said that his company does not encounter the breaking of frames now in its regular service, but that this fact is attributable to proper supervision, inspection and stitch-in-time methods, keeping rivets tight, wearing parts properly lubricated and natural wear corrected. The same sort of thing applies to many other truck units.

Mr. La Schum said that, while there should be an improvement by way of the development and the standardization of such equipment as odometers and radiator guards, and of greater accessibility of gasoline filling openings, the records of reliability of modern motor vehicles are excellent. With regard to maintenance costs, the following percentage figures were presented, not including drivers' wages, depreciation, interest and insurance:

Gasoline	30.00
Cylinder Oil	2.25
Tire Costs	2.50
Painting	1.30
Body Repairs	4.75
Chassis Repairs	35.20
Garage Expenses	24.00
	100.00

The speaker advocated the use of non-adjustable carbureters when feasible and teaching the drivers that a rich mixture, which may make possible the negotiation of a given grade without shifting gears, results in a 35-per cent excess of fuel consumption, and increases carbonization.

In speaking of the operation of over 800 gasoline trucks in Atlanta, Buffalo, Chicago, Cleveland, Detroit, New York City, San Francisco and the City of Washington, Mr. La Schum stated that in 1922 these trucks worked 306,348 days of 8 hr., their total mileage being estimated to be 9,190,000 miles. During that year there were only 6200 emergency calls for help for these trucks. The causes of these calls are shown in the following percentage figures:

Engine Bearings	0.8
Spark-Plugs	5.9
Ignition System	9.1
Carbureter	8.6
Gasoline Lines Clogged or Leaked	7.6
Broken Fans or Fan-Belts	9.3
Radiators	1.1
Water-Pump or Line	1.6
Radiators or Pumps Frozen	0.2
Governors	0.5
Steering Gears	3.3
Clutch	3.0
Propeller Shaft	1.5
Universal Joints	1.1
Transmissions	3.0
Differentials	0.5
Rear Axles	0.9
Radius Rods	0.9
Drive Chains	3.8
Wheels	1.5
Springs	1.8
Brakes	2.2
Tires	3.3
Lights	1.0
Accidents	1.6
Out of Gasoline or Oil	3.1
Miscellaneous	23.8
Total	100.0

In other words, there were only 50 cases of bearing trouble, and rarely a case of a full set of connecting-rod bearings burning-out.

The spark-plug trouble was due almost without exception to drivers using a choker and fouling the plugs by too rich a mixture. The spark-plug replacement has been less than one-half of one spark-plug per truck per month. In the above table "ignition system" does not include spark-plugs.

During last year, 226,716 working days were obtained in the same cities as those named above from 722 electric trucks. There were less than two emergency calls per truck, the total mileage being 4,870,752. Approximately 91 electric motors burned-out, due in many cases to overloading. There were 366 cases of exhausted batteries; that is, a battery was exhausted once per truck per two years. Controllers caused 12.1 per cent of the troubles; steering-gears, 6.2 per cent; axles, 1.5 per cent; brakes, 5.0 per cent; springs, 1.3 per cent; drive chains, 11.6 per cent. Mr. La Schum said that chain troubles have been eliminated in modern electric-truck operation.

Mr. Winchester argued that a standardized form of cost analysis is needed to enable different operators to compare their results, certain standardized forms of bookkeeping that have been used being too complicated. He asked whether the direct comparison of mechanical operation costs should be based on the average cost from data of installation by individual truck; by fleet operation, that is, by make and model; or by a division of the cost by year of installation. He expressed the opinion that simplicity should be the keynote.

The speaker did not concur with Mr. La Schum's conclusion that first consideration should be given to the organization of maintenance and not that of operation. Mr. Winchester said that the operation organization is burdened with the reduction of items of expense developing fixed charges, these apparently constituting 65 per cent of the total operating charge. The maintenance organization controls the items of variable cost; these being largely mechanical expenses, and in Mr. Winchester's opinion amounting to about 35 per cent of the total. Whatever unit cost is taken as a base, careful routing and planning are the greatest factors in reducing expense. The efficiency of trucks from the standpoint of variable charges, such as those for gasoline, lubricating oil and grease, depends largely upon vehicle design and generally speaking no great economies can be effected in this connection in individual models. The organization of maintenance should render the organization of operation efficient engineering and general service so that the unit cost may be duly minimized.

Mr. Winchester was of the opinion that the selection of an engineer to manage a fleet of vehicles should not involve duplication of experimental engineering work done at the various vehicle factories or elsewhere, but that all available engineering data should be availed of in fleet operation.

He urged that a mechanical-installation sheet be prepared along standardized lines to furnish the truck operator with complete mechanical specifications of the type of installation in which he is interested. Such a sheet should provide for the recording by the manufacturers of structural changes in trucks to assist the operator in ordering material for a given truck. Items mentioned by Mr. Winchester were cylinder oversizes and gear-ratio changes. In his opinion the catalogs supplied in the past do not meet the present condition. If fleets are to be operated efficiently it will be necessary to have these details, the general information contained in the parts lists being inadequate. Mr. Winchester suggested also that the truck industry do more in the way of supplying fleet operators with complete engineering data on fits for the assembling of such parts as pistons and bearings. This would be particularly helpful in overhaul work. This, in conjunction with the need of a fleet basis of repair rates, is in Mr. Winchester's opinion a crying need, particularly in connection with the work of small fleet operators.

With regard to tire equipment, Mr. Winchester said:

> My experience definitely proves that the type of tire employed has a definite relation to the efficient operation of the truck itself. We as an industry have heard certain claims made by the tire manufacturers for different types of solid, pneumatic and cushion tires, and also by wheel manufacturers on the subject of reducing operating cost. I believe that this is the most vital problem in considering tire installation. I feel sorry for the operator who paid considerable attention to the various claims made for pneumatic tires in the last few years for trucks of 3½-ton capacity and over. I also believe that certain types of tire for the lighter equipment can be employed to advantage. Why should we consider tire cost only in view of the differences in repair and mechanical-upkeep cost on various types of tire that indicate a large saving can be made? To illustrate this point I give the following:

Type	1	2
Time in Operation, months	27	25
Total Tire-Cost per Mile	$0.0273	$0.0167
Total Repair-Cost per Mile	0.1043	0.0729
Total Mechanical Cost per Mile	0.1759	0.1317

> Based on this difference in cost, presuming that 100 trucks ran 25 days per month, 12 months per year and 35 miles per day, we have a total mileage of 1,000,050 miles per year. The difference in the mechanical-repair cost in this case represents a saving of $33,600 per year, while the difference in the total mechanical cost represents a saving of $46,200 per year. These figures indicate why we should keep tire records.

Mr. Winchester made a plea also for the formulation of a standard form of distribution of chassis overhaul cost. He said that his experience indicated that a 5-ton engine after running from 18,000 to 24,000 miles should be overhauled in a labor-hour classification of not over 90 hr.; while the total repair cost including all charges should not exceed $900 average. In commenting upon the analysis of troubles given in Mr. La Schum's paper, Mr. Winchester said that results vary with the types of vehicle used. Road conditions and the average age of the fleet make a big difference in percentages. He said that he seldom hears of troubles relating to spark-plugs, carbureters, gasoline lines clogged or leaking, governors, propeller-shafts, universal-joints, radius-rods, drive-chains, wheels, brakes, oil shortage or tires; this condition being due largely to systematic inspection. The adoption of a strainer-funnel of proper design eliminates for the most part clogging of gasoline lines. The spark-plug consumption of the motor-truck fleet that Mr. Winchester supervises has been approximately one spark-plug per cylinder per year. The design of the oiling system plays an important part in this connection.

Mr. Winchester expressed the opinion that a fleet which operates over an extended area and does not come into a central garage each night, but is left to the care of the individual operator except for a bi-weekly inspection, can be operated very efficiently with a reserve equipment of 1 truck in 16; with efficient central control and a systematic method of upkeep this quantity of reserve equipment can be very materially reduced.

Mr. La Schum said that a 2-ton electric truck in proper condition with varying loads, will make regularly 30 to 35 miles per day on a single charge.

THE SERVICE-MAN AND THE CAR-OWNER

Relations Between Them the Chief Topic at Minneapolis Section Meeting

The relation of the service-man to the car-owner who makes use of his service, was the principal topic at the meeting of the Minneapolis Section, held on April 4, at the Manufacturers' Club.

C. M. Stroud of the Oakland Service Co. ranks an even disposition as one important qualification of a good service-man. So many car-owners feel it their duty to abuse the service-man, not realizing that the service organization could not exist if it did not adequately serve the car-owner. Service-men are human, and the man who gets real service is not the man who insists that his work be rushed through before everything else, but the man who drives in and in a pleasant way says, "Well, boys, the old car is not running as it should today. Try her out, fix up the trouble, and call me when the car is ready."

Unfortunately, the repair business has a reputation for building up repair bills and giving little in return. This charge is founded on a misunderstanding of the situation. Few car-owners know enough about a car to figure the cost of labor and parts needed for repairs. As a rule, a car gets very little attention unless it breaks down. Nearly every company that sells cars invites the owner to bring in his car for examination at least once a month, but very few take advantage of this offer. Regular inspection and making repairs as needed would save many dollars in repair bills and cars so maintained would give better service.

In discussing what should be expected of a service-station, Mr. Stroud emphasized the sales value of satisfaction. Satisfied owners are the best salesmen and good service is the

one thing that makes a car-owner brag about his car. Give a man all he can reasonably expect when he brings his car in for repairs and he will keep coming whenever he is in need of repairs. If the selling company would only make an effort to have the service department the talk of the town, they could hold their car-owners and the small garage men would not have much to do. The modern service-station is equipped with up-to-date tools for quick repairs and mechanics who know the car. The old type of "Greasy Bill" mechanic is being replaced by the mechanic who takes pride in his work.

Mr. Stroud pictured the ideal service-station as big enough to accommodate a large number of cars on the ground floor without crowding, so that cars could be driven in and out without damage. There will be no guessing school connected with the establishment. Inspectors will examine a car, tell the owner what is needed, how much it will cost, and when the car will be ready. While specialists in ignition, carburetion, etc., make the necessary repairs, the owners will be able to wait comfortably in attractive waiting rooms provided especially for their convenience. Mr. Stroud's paper was followed by a discussion from several angles of the details of service-station management, including the use of the so-called flat-rate charge for making repairs of all kinds to different classes of automotive vehicle.

The second paper, Advantages to the Twin Cities of the Ford Factory Project, was given by R. E. Hilton, secretary of the St. Paul Association, in place of Col. L. H. Britton of the same organization, who was originally scheduled to address the meeting.

Mr. Hilton attributed the development of Minneapolis and St. Paul to superior waterpower and the favorable freight rates the Twin Cities could exact because of advantages in river transportation. The need for the decentralization of huge industrial enterprises, the waterpower and the possibilities of profitable river traffic have attracted Mr. Ford to the Twin Cities, and the building up of that river traffic is one of the most important advantages expected from the location of the new Ford factory there. The resumption of river traffic would encourage the export of grain via New Orleans, instead of the more expensive Lake route. The Ford plant would also mean building up Minneapolis and St. Paul through the men brought in and the publicity given the new Ford project.

The May meeting of the Minneapolis Section will be held at the Manufacturers' Club on May 2, beginning at 8 p. m., after the usual informal supper. The North East Electric Co.'s film, Electricity in the Motor Vehicle, will be shown, and J. L. Larson of the college of agriculture, University of Minnesota, will speak on Some Experiences in First Breaking Peat Land. Mr. Larson's talk will be based on exhaustive tests that have led to conclusions of fundamental importance to tractor designers.

E. J. Lees Glenn Muffly

THE TWO AUTHORS OF THE PAPER PRESENTED AT THE APRIL MEETING OF THE DETROIT SECTION

GROUND GEAR ADVANTAGES EXPLAINED

Improved Efficiency and More Quiet Running Warrant Slight Additional Expense

Objectionable sound-waves are produced by errors in gear teeth greater than 0.0003 in. and, to avoid the occurrence of errors beyond this limit, it is necessary to generate tooth curves after hardening instead of before. This was the opinion expressed by Glenn Muffly, of the Lees-Bradner Co., who addressed the Detroit Section of the Society on the evening of April 6. As evidence that the gear-noise subject is a live one, over 250 members and guests attended this meeting to hear the description of one process of gear grinding and a discussion of tooth forms.

In the process described by Mr. Muffly, the gear-tooth profile is generated by rotating the gear past a large grinding wheel whose flat surface represents the face of a flat-sided rack tooth meshing with the gear that is being ground. The gear is indexed automatically and moved one space after each of the tooth surfaces has been rolled over the wheel twice. The indexing mechanism has been studied carefully to control the spacing of the teeth to a high degree of accuracy. The grinding wheel is 30 in. in diameter, its large size making it unnecessary to dress the wheel until one or more gears have been finished. The dressing operation is simple since the grinding or working face of the wheel is a perfectly flat surface. It is possible to generate modified involute tooth forms on this machine so that the tooth profile will be a correct involute when the gear is working under

R. E. Wilson, Mid-West — C. T. Myers, Metropolitan — T. J. Litle, Jr., Detroit — O. M. Burkhardt, Buffalo

SOME OF THE RECENTLY ELECTED SECTION CHAIRMEN

load, the modification being made to compensate for the deflection of the loaded tooth. These modifications are very minute as compared to those that have been made in the past, and Mr. Muffly said that the tooth form his company recommended is so near the true involute that it would pass as a perfect involute tooth when tested by the usual methods.

A demonstrating device that represented two rolling wheels acting as involute base circles with steel tapes running between them to represent tangents to these base circles was shown at the meeting. It was possible to generate tooth curves with this model and compare their relative forms when generated with the base circles placed at several different center-to-center distances. In other words, the base-circle diameters were kept constant, but the circles themselves were fixed at varying centers to generate a series of involute curves. In this way, Mr. Muffly demonstrated that an involute gear has no inherent pitch diameter of its own and only acquires one when it is meshed with another gear, a hob, a cutter or a grinding wheel. There is nothing stable about the pitch diameter in the involute system, and two gears running on a center distance 0.010 in. greater than standard, theoretically are running just as accurately as if they were meshed on the intended center distance, except, of course, that teeth run in this way should be made thicker to reduce the backlash to a reasonable amount. The change in center distance simply causes a change in the pressure-angle and moves the rolling surfaces farther down the same basic involute curve.

New Possibilities With Ground Gears

Gear grinding not only aids the solution of the noise problem, but it opens the way for design changes that were impractical because hardened steel gears could not be made to run quietly. More development in the application of four-speed transmissions will take place and engines can then be run at their most economical speeds a greater part of the time. The public has demanded flexible performance on high gear because of the objection to the noise of the transmission when it is operated in second gear. Grinding of gear teeth opens up the possibilities of a really high fourth speed and we may even see transmssions in which there is no direct drive, thus making all speeds uniformly efficient. Placing the propeller-shaft on another and lower center will permit the lowering of the body floor and the reduction of the universal-joint angle. Ground gears are also more efficient because they are mechanically correct and this high efficiency will result in increased fuel economy. Transmission shafts will have to be designed so that all of the gear teeth can be reached with a grinding wheel; cluster gears made in one piece with the shaft will have to go. It is possible that there will be a return to spur gears for timing purposes because of the more quiet operation due to the ground teeth. The change from helical to spur gears can be made very easily since the grinding process handles an odd diametral pitch as well as any standard pitch.

The discussion at the meeting took the form of submitted questions and answers, the scheme so successfully used at recent meetings of the Detroit Section. E. J. Lees, who collaborated with Mr. Muffly in the preparation of the paper, gave the following data relating to time required for grinding:

Number of Teeth	Time per Tooth, Sec.
15	14.4
17	13.2
18	10.8
21	9.6
25	9.6
29	8.4

These teeth are 6 to 8 pitch, the wheel is rotating at a peripheral speed of 5000 ft. per min. and passes twice over one side of the gear tooth. About 0.003 in. is removed by each cut. The grinding is done wet so that the surface hardness of the tooth is not affected. One manufacturer has determined the cost of grinding as $1.75 per transmission; another said it cost a few cents more than the cost of the finishing cut that was replaced by grinding. In any case, a considerable saving is made by eliminating tear-downs of completed transmissions that are too noisy to pass the final inspection. Mr. Muffly believed that gear life was lengthened by grinding, because the elimination of spacing and profile errors insured smooth running, uniform velocity and the elimination of the alternating loads that would be present without these conditions.

The statement was made that bevel gears could not be ground on the machine described, or on any other now on the market, but that this would probably be accomplished eventually. Backlash can be reduced materially with ground gears provided the other machine work is accurate and the center-to-center distance of the gear-shafts accurately maintained. No comparative efficiency tests had been made between individual gears or transmissions with and without grinding the teeth. It was the speaker's opinion that a small pressure-angle is desirable from the standpoint of quietness because it makes it easier to hold down the backlash. On the other hand, in transmission practice the gears have relatively small numbers of teeth and the tooth load is large, so it is advisable to use a larger pressure-angle to avoid interference and distortion. The large pressure-angle avoids under-cutting the teeth on the pinions and provides a stronger tooth form. About 20 deg. is a good pressure-angle for transmission gears and about 14½ deg. is suitable for timing gears. Odd pressure-angles are frequently used when it is found that the standard angle would result in tooth interference.

Officers of the Detroit Section were elected at the April meeting for the coming Section year. Thomas J. Litle, Jr., was accorded the honor of election to the chairmanship. Mr. Litle has been active in the affairs of the Detroit Section for the past year, serving as its secretary. He was partly responsible for the success of the Production Meeting held in Detroit last fall and is an active member of the Research and the Meetings committees of the Society. Don T. Hastings was elected to the office of vice-chairman, Milton Tibbets becomes the Section's treasurer, and K. L. Herrmann, who has been instrumental in bringing production subjects before the local and national meetings, will assume the duties of secretary.

BUFFALO LEARNS BY SEEING

The development of electricity in general and particularly as applied to the automobile was shown at the Buffalo Section's meeting on April 13 in the North East Electric Co.'s new film. After a reel that outlined the development of electricity to its present important place, six reels were devoted to a graphic study of ignition, the starter and the generator. G. R. Fessenden of the North East Electric Co. explained the processes demonstrated by animated diagrams and the labors of the North East Electrified Dwarfs, clearing up some of the more obscure points in ignition and the operation of the separate and single unit starter-generator.

There will be no meeting of the Buffalo Section in May.

FOUR-WHEEL BRAKES DETROIT TOPIC

The next meeting of the Detroit Section will be devoted to a paper and discussion of hydraulic four-wheel brakes. The meeting will be held on the evening of May 17 in the General Motors Building. The paper will be read by M. Lougheed, engineer of the Four-Wheel Hydraulic Brake Co. The meeting will start at 8 o'clock and will be preceded by an informal dinner at 6:30.

TRANSPORT CORPS TESTS VALVES

Concludes Silicon-Chromium Alloy Gives Best General Service Result

The results of an extensive test of exhaust-valve materials made by the Motor Transport Corps were presented to the members of the Washington Section by Arthur W. S. Herrington at the meeting held on April 6. A large number of

valves of different construction and materials were subjected to warpage, burning and scaling tests to select the valve design and metal best suited to the service of the Corps. The tests for warpage were made by running a set of each kind of valve in a Class B truck engine, the compression of which had been raised to 5.33 to 1 to increase the severity of the test and shorten the time required. Each valve was checked for eccentricity of the stem and the seat, properly ground in place, the engine run for 8 hr. at 1000 r.p.m., and the valves again checked for eccentricity.

Resistance to burning was judged by running valves in the engine after relieving their seating faces to a depth of about 0.02 in. on a sector 1½ in. long. This allowed leakage of the exhaust gases past this sector and resulted in exaggerated burning and scaling of the valve face. The change in the depth of this groove after the test run gave an indication of the relative resistance of the valves to burning and pitting.

To check the resistance of the several materials to excessive heating, samples were placed in a gas furnace and maintained at a temperature of 1550 deg. fahr. for a period of 5½ hr. After that severe treatment, they were removed and all of the loose scale was brushed off of them. The weight was then taken and compared with that recorded at the start of the test, the difference indicating the relative ability of the different materials to withstand oxidation at high temperatures. It was noted that the steels with the higher content of sulphur were the ones that were found to be most badly scaled.

It was concluded as a result of these tests that the most desirable material specification for valve-steel at present, judged by the method used and for the service encountered in Motor Transport Corps vehicles, was as given at the top of the next column. This alloy is known commercially as silichrome.

Carbon, per cent	0.450
Manganese, per cent	0.560
Phosphorus, per cent	0.029
Sulphur, per cent	0.010 max.
Silicon, per cent	4.020
Chromium, per cent	9.300
Nickel, per cent	0.050

Officers of the Washington Section for the coming year were elected at this meeting. C. H. Warrington will take the helm as chairman and this insures an active year, judging by the interest that Mr. Warrington has taken in the Section's activities in the past. Other officers elected were: A. W. S. Herrington, vice-chairman; and C. H. Young, secretary and treasurer.

The next meeting of the Washington Section will be held on the evening of May 4 at the Cosmos Club. Major F. S. Besson will address the members on the subject of Highways and Traffic.

W. F. GERHARDT ON MILITARY AIRPLANES

May 1 is the date of the next Dayton Section meeting at the Engineers' Club. At 8 o'clock, after an informal supper at 6:30 p. m., members of the Dayton Section and their guests will hear W. F. Gerhardt on Fundamental Principles of Design of Military Airplanes. Mr. Gerhardt's experience as an aeronautical engineer with the flight test section of the Air Service, at McCook Field, has amply qualified him to speak of the principles on which military airplanes must be built for successful flight.

F. S. DUESENBERG AT INDIANA MEETING

Engineering Information from the Race Track is the topic on which F. S. Duesenberg, chief engineer of the Duesenberg Automobile & Motors Co., Inc., will speak at the May 3 meeting of the Indiana Section. The meeting will be held at the Lincoln Hotel, Indianapolis, and will begin at 8 p. m., after an informal dinner at 6:30.

APRIL COUNCIL MEETING

THE meeting of the Council held in Cleveland on April 25 was attended by President Alden, First Vice-President Crane, Vice-President Masury, Councilors L. R. Smith and A. J. Scaife, Past-President Bachman and Mr. O. A. Parker.

The financial statement as of March 31, 1923, showed a net balance of assets over liabilities of $121,198.38, this being $2,912.51 less than the corresponding figure on the same day of 1922. The income of the Society for the first 6 months of the current fiscal year amounted to $137,478.97. The operating expense during the same period was $138,266.69.

One hundred and thirty-six applications for individual membership, two for affiliate membership and one for student enrollment were approved. The following transfers in grade of membership were made: From Junior to Associate, Stuart Cowan; Associate to Member, F. R. L. Daley, Frederick H. Ford, Norman W. Lyon, A. L. Swank, George C. Lees, James L. Myers, Paul M. Stone, Paul B. Taylor, George Hutton, J. H. Holloway, A. R. Keagy, H. C. Olivier, E. S. Anderson, C. E. Patterson and M. J. Marty; Junior to Member, J. McElroy, S. R. Swenson, G. W. Klinger, H. A. Hansen and Earl H. Smith; Associate to Service Member, George W. Graham; Foreign Member to Service Member, D. D. Pullen; Member to Foreign Member, Joseph Kirschmann. Eleven transfers were considered but will not be completed pending observance of additional formalities.

It was reported that up to April 25, 1923, 323 applications for membership had been received during 1923, as compared with 268 received during the first 4 months of 1922, and 324 during the corresponding period of the previous year.

The following appointments to the Standards Committee were made:

AERONAUTIC DIVISION—Paul C. Zimmerman
BALL AND ROLLER BEARINGS DIVISION—H. Wickland
IRON AND STEEL DIVISION—R. J. Allen
LUBRICANTS DIVISION—A. B. Dawson
MOTORBOAT DIVISION—James W. Hussey and H. F. Sailor
NOMENCLATURE DIVISION—H. M. Crane
TRUCK DIVISION—C. B. Veal

The following appointments were confirmed:

AERONAUTIC DIVISION—Otto H. Hamm and E. W. Rounds
ISOLATED ELECTRIC LIGHTING PLANT DIVISION—L. W. Holt
MOTORBOAT DIVISION—W. A. Roos, Jr.

The following were designated to serve as members of the Tire and Rim Division of the Society:

J. G. Vincent, *Chairman*
B. B. Bachman H. M. Crane
A. J. Scaife

The subject of the simplification and reduction of the number of tire and rim fits was assigned to the Division.

Walter C. Ware was appointed to serve this year as Second Vice-President representing Marine Engineering, in place of E. J. Hall who resigned.

The next meeting of the Council was tentatively scheduled to be held at Spring Lake, N. J., on June 18.

Cracking Processes in the Petroleum Industry[1]

By Frank A. Howard[2]

As used in the petroleum industry, the term "cracking" signifies generally the conversion by decomposition of a heavy or viscous oil of high boiling-point into a lighter, free-flowing oil of lower boiling-point. Specifically, the term is applied almost universally to that particular species of decomposition by which gas oil or fuel oil is converted to yield a substantial percentage of gasoline.

The art of cracking goes back approximately 100 years, not of course in the modern petroleum industry, which has not had that length of life, but in the allied gas and coal-distillation industries. Animal and vegetable oils, waxes, fats and resins appear to have been subjected to an operation that we should today call "cracking," in the very earliest days of the gas industry, for the purpose primarily of converting them into illuminating and fuel gas. Almost as early, various natural bituminous substances, such as coal, shale, lignites and more rare mineral deposits that came very near to being solidified petroleum oil, were subjected to destructive distillation, both for gas production and for the production of light-oil distillates. The earliest general use of this method of destructive distillation for the purpose of causing the decomposition of complex bitumens into lighter oils appears to have taken place in connection with the shale and coal oil industry in England, where cracking processes of this description were very early utilized to increase the yield of refined oil or kerosene.

Highly Developed by Americans

Cracking for this purpose became a standard operation in the petroleum industry soon after it got on its feet commercially in America, and the process was highly developed in American refineries. By the aid of this method, the supply of refined oil, which was at that time the petroleum product in greatest demand, was very greatly increased. In the case of many crude oils the yield of kerosene obtained by cracking equalled the yield of natural kerosene, so that in effect the kerosene production was in these instances actually doubled by cracking.

In the early years of the present century, when the demand for gasoline began to outstrip the demand for kerosene, it was natural that the oil-refiner should turn to his prior cracking processes for inspiration and help in solving the new problem. The earliest process for cracking to produce gasoline that proved successful on a large commercial scale was that developed by Dr. William M. Burton and his associates, of the Standard Oil Co. of Indiana. This process was a pressure-distillation method, the details of which were worked out so successfully that within 2 or 3 years there were several hundred stills operating according to the method in use, not only by the Indiana company but by a large number of licensees as well, located in all parts of the United States. The success of the process and its widespread use may be attributed not only to its intrinsic merits, but also to the circumstances that its details were worked out in such a manner that it fitted into existing refinery processes and organizations so perfectly, requiring the minimum of special knowledge in either construction or operation, and the minimum change in the accepted refinery practices aside from the pressure distillation itself.

The Burton Process

The Burton process, of course, was not the only one that came forward at this time, for the subject of an increased gasoline supply was one of great importance to the whole industry, and refiners, as well as chemists, engineers, and outside inventors and scientists of all descriptions, were diligently at work on other processes. The historical background of the cracking art, involving not only petroleum refining but the earlier industries of gas manufacture and coal and shale distillation, gave a fertile field in which inventors seeking to improve cracking for the production of gasoline could operate. It will be remembered that the Federal Government itself became interested in this matter, through the Bureau of Mines, and that much publicity was given to a process known as the Rittman process, the initial work on which was done under the auspices of the Bureau of Mines.

Unfortunately, in many instances, perhaps the majority of instances, the investors and promoters of the numerous cracking processes that began to clamor for public attention and financial backing very soon after the Burton process became generally established, either were unfamiliar with or failed to point out the historical background of the problem. It was believed by most persons not familiar with the details of the industry that cracking was an entirely new phenomenon and method; that the Burton process was the only known means of accomplishing it; and that anyone who was able to produce gasoline by cracking in a manner different from that of the Burton patents would be assured of a fortune.

The Facts of the Matter

The facts of the matter were very different; cracking was not essentially new, nor was it by any means true that the Burton process was the only method by which gasoline could be obtained from the heavier oils. Almost anyone of the hundreds of prior cracking processes that had grown up in the three related industries of petroleum, gas and coal were available, sometimes without any change at all and sometimes with only the very simplest changes, for the production of gasoline from heavy oils. As in every other practical proposition, the dollars-and-cents results were the final criterion. For one reason or another, almost none of these competitive processes could be actually used on a large scale by the average petroleum-refiner with any profit to himself. The gasoline yield was too small, the quality bad, the losses too high, the processing costs excessive, the equipment too dangerous or too costly or some other single disadvantage or combination of disadvantages worked to outlaw the process from the practical refinery. At least half a dozen sizable fortunes have been sunk in efforts to convince the refining interests of the Country of the practical value of the more energetically promoted of these processes. Much that was of real merit was involved in many of the processes, and some of them actually gained a precarious foothold in the industry.

It was inevitable that a development of this kind, involving such a large industry and of such great importance financially, should become the subject of a host of patents. Several hundred patents have been issued dealing with cracking processes in the last 10 years. The lack of any general knowledge on the part of the public as to the nature of a patent right is in a large measure responsible for the confu-

[1] From an article in *The Lamp*, published by the Standard Oil Co. of New Jersey

[2] M S A E—Manager of the development department, Standard Oil Co. of New Jersey, New York City.

sion that has existed with respect to cracking patents and with respect to their speculative or investment value. It should be understood that a patent is not the grant of a right by the Federal Government to practise a certain invention, make a certain machine or use a certain process. Every person has an inherent right to engage in any lawful business, and this right is neither extended nor limited by the grant of a patent to him for an invention that he proposes to use. The right that the grant of a patent does establish is not the right to practise the patented invention, but solely the right to prevent others from practising the specific novel point of the invention.

It is almost universally the case that an invention consists of a combination of something that is new with something that is old. In the art of cracking oil, the patents, without any exception so far as we know, do not even purport to cover fundamentally the operation known as "cracking." They obviously could not do so, for this operation, under the same or another name, is at least 100 years old. What the patents do cover, each of them, is some particular combination of steps or pieces of equipment arranged for use in some definite fashion. Perhaps no single one of the pieces of equipment or the steps of procedure will be new in themselves; perhaps the novelty will consist only in its application in that particular combination.

In other cases, the novelty may consist in the addition of some single new step or piece of equipment to an apparatus or process that was in toto old with the exception of that new part. For example, in the cracking art, probably two-thirds of the patents that have been issued relate to improvements in the same general method used in the Burton process, the distillation of the heavy oil under pressure. These improvements take all forms; they deal with the temperatures and pressures at which the distillation takes place, the form of the equipment used, the treatment of the resulting products and every imaginable variant. The Burton patents themselves, although generally regarded as the pioneer patents in this field of gasoline production by pressure distillation, do not purport to cover the mere act of pressure distillation as carried out in a particular fashion, which, in the judgment of the Patent Office, was new with Burton and his associates.

Mostly Infringements

It follows from the above that almost all of the patented cracking methods, which have formed the subject of the large number of patents issued within the last few years, are themselves infringements of some one or more other patents, depending upon the basis upon which the inventor started to work. A situation of this kind naturally becomes more complex in proportion to the number of patents that are coexisting in the same field at any particular time. The importance of the cracking art naturally attracted inventors to such a great extent that there is perhaps no single patent situation which is more confused than this one. The situation has been made even worse by reason of the fact that the Patent Office has been laboring under difficulties in the way of inadequate funds and an inadequate staff during the past 5 years, resulting not only in the grant of some patents, the validity of which may be seriously questioned, but also in almost indefinite holding-up of applications for patents.

A Licensing Patent

The Standard Oil Co. of New Jersey has been a licensee under the Burton patents and has operated large numbers of Burton stills for many years. It has during that period devoted considerable amounts of time and money to research and experiments on cracking and as a result of this work has been able to improve greatly the efficiency of operation of its Burton equipment. A further and more important result of the same work, however, has been the development of a process, known as the "tube-and-tank process," that is just now beginning to be used extensively in the refineries of the Company. Based on the experience with it up to the present time, it is believed that this method will be in many respects superior to the Burton method. It is not the intention of the Company to attempt to monopolize the tube-and-tank cracking method but on the contrary, a liberal licensing policy has been adopted with respect to this process.

RESERVE OFFICERS TRAINING CORPS

THE lessons taught by the World War took root in the minds of our Country's legislators, with the result that the Reserve Officers Training Corps, previously a practically dormant and inactive organization, became an important force, both in our colleges and in the military world. Generous appropriations contributed the stimulus toward making it an active and well-planned organization that immediately took its rightful place in college work.

Despite the aversion for all things of a military nature, created by the years of warfare, the courses of military instruction were made so attractive that students were glad to take them. Uniforms, commutation of rations and summer camps were features that appealed to the average college man. The courses, instead of being confined to close-order drill and tiresome ceremonies, were broadened to include lectures and practical work on subjects that were not only of vital importance to an officer, but interesting to the student. These things have contributed toward making military one of the most popular courses in the modern college.

The courses as presented in the colleges are intended to give the basis upon which may be added the finishing touches necessary to make good officers. These men, placed in reserve, could be called forth in time of war, given a short intensive training suited to the needs of their branch of the Service, and made ready in a short time for active and useful duty. Aside from the military value of this force of Reserve Officers, the civic value of the training received under the Reserve Officers Training Corps is immense. It has been said that a man who wins his commission in the Artillery has sufficient training to be a good civil engineer. The same sort of thing might be said in connection with the Signal Corps and electrical engineers. The Motor Transport Corps offers a course in automobile mechanics hard to beat in any technical school.

The discipline and obedience to authority exemplified in the old-fashioned military regimes, are not entirely dispensed with in the modern course. Enough close-order drill and infantry maneuvers are assigned the student to give him a thorough idea of the value of discipline and the poise that is the making of a good officer. This work is given in the earlier part of the course, while the last 2 years are devoted more to the theory and specialized study of the subjects directly pertaining to the branch of service that the student intends to enter.—C. Y. Thomason in *Coast Artillery Journal.*

TRAFFIC SIGNALING

THOSE responsible for the control of the rapidly increasing motor-vehicle traffic on our city streets and State and county highways have been confronted with a problem that under the best conditions is neither simple nor easy. No traffic in the history of the world has developed at such a rapid rate as highway traffic. So, it is not surprising that, in meeting this unprecedented growth, methods have been adopted which, if more time had been available, would have shown a greater degree of uniformity and a closer adherence to some of the principles that have, through a long period of years, evolved into established practice in the control of other classes of traffic.

We shall probably always have traffic laws, regulations and lettered signs for the highway, but we may expect continued development of signaling, both audible and visual, for highway-traffic control. Users of highway vehicles are not the only people who have had to face the problems of traffic control and signaling. Many of the existing marine and railroad signaling methods are the result of years of study and have become stabilized through legislative enactments. An acquaintance with their underlying principles is helpful in any study of traffic control and signaling.

In general, the conditions that affect traffic and need to be indicated to the vehicle operator are those that in any way retard or obstruct free traffic movement. Naturally, any conditions that affect the integrity of the roadway as a structure or support for the vehicle constitute an obstruction. The most frequent class of obstructions to vehicle movement is the presence of another vehicle. The degree in which one vehicle in the path of another constitutes an obstruction varies greatly with the nature of the channel of traffic. The braking power of the vehicle, that is, the distance in which a stop can be made, is a factor in determining the location of any form of traffic signaling and the indication that it should display. In all traffic regulation it is necessary to recognize that one vehicle may at certain times have the right of way or precedence over another.

Railroad trains are classified according to what is called "superiority." Precedence of one train over another may be conferred by right, class or direction. Superiority by right is conferred by train-order. First-class trains are superior to second-class trains; as between trains of the same class on a single track, those moving in a given direction have superiority. Without our recognizing the fact, perhaps, our highway vehicles group themselves into the same classes. The whistle of the traffic policeman, or his hand signal, establishes precedence by right. Our fire engines, ambulances and United States mail wagons would in railroad language be called first-class trains. They have the right of way over other vehicles. In a number of cities traffic on streets running in a given direction has precedence over traffic on streets running at right angles to them.

Signal Systems

The three principal systems of signals used for the control of traffic are (*a*) fixed signals, (*b*) vehicle signals and (*c*) hand signals. Fixed signals indicate conditions affecting the movement of traffic; under this heading may be grouped lighthouses, beacons and buoys for marine traffic; pylons, ground-lights and other landing-field signals for air traffic; block-signals, interlocking signals, train-order signals, switching signals and signs on railroads, and traffic signals, road-signs and railroad-crossing signals on highways.

Signals displayed by vehicles indicate their class, location or direction of movement. This class includes the running and the anchor lights of vessels, the running lights of aircraft, the classification signals and markers of railroad trains and the usual lights displayed by highway vehicles. Hand signals may be defined as any signals given with the hand, a flag, a lamp, or a disc by the operator of a vehicle or by a person controlling the movement of traffic.

Our railroad friends have some rather good definitions of signaling; the handling of heavy trains at high speed of course requires very definite and simple signal-codes. There are three conditions that railroad signals are primarily intended to denote: (*a*) that the way is not clear; (*b*) that the train should be brought under control so as to enable a stop to be made quickly; and (*c*) that the way is clear. The indications of these conditions are, respectively, "stop," "caution" and "proceed." When the railroad man uses the word "indication," he does not mean the form, color or appearance of a signal, but the wording or language that the signal speaks. He uses another word to define the form, color, motion, position or other appearance of the signal, namely, "aspect." In describing a situation in which it is proper for a train to proceed, he would say that the *condition* is *clear*, that the *indication* is *to proceed* and that the *aspect of the signal* is *an arm in a vertical position* by day and in addition, at night, a green light. These terms appear to be sufficiently clear and precise to be used in connection with all forms of traffic signaling to which they may apply.

It is of course highly desirable that, so far as possible, uniformity in all types of traffic signaling exist. We hardly need "port" and "starboard" lights on automobiles; though, if numbers of them were maneuvering at large over a field instead of running in parallel paths on highways, such lights might be very desirable. There is little chance for conflict between marine and land signals. Thousands of miles, however, of our important highways run parallel to and closely alongside of our steam railroads, and many hundreds of miles of electric railways actually occupy our streets and roads. Furthermore, we have in the United States thousands of crossings of highways and railroads at grade. It is perfectly clear that our systems of railroad and highway signaling, as regards fixed signals, vehicle signals and hand signals, should be of sufficient uniformity to avoid misunderstanding or conflict, wherever signals used in the control of one class of traffic may be seen and wrongly interpreted by the operators of vehicles in the other class of traffic.

It is also highly important in any system of signaling never to use an indication that is more restrictive than is actually required by the conditions. I have never encountered anything more absurd in signaling than to follow another car down a long hill, my own car and that ahead running at about 25 m.p.h., with the leading car displaying in flaming red letters the word "stop." This is almost the ultimate in crying "wolf," and there is nothing worse in any system of signaling, unless it be a direct conflict of indications, than continually crying wolf by giving a more restrictive indication than the conditions warrant. Certainly, the most restrictive indication that the car ahead should have displayed is "caution." I believe that a caution indication rather than a stop indication, should be the one displayed by the tail-lamps of highway vehicles.

The question of signaling at grade-crossings of railroads and highways demands the most careful study and the determination of a sound basis for the indications to be displayed and the aspects of the signals to denote them. Probably there is no phase of the signal problem that is more confused, nor on which there has been so much loose thinking.

Signaling in some of its forms is a very old art. Railroad signaling as an art is less than 100 years old. Highway-traffic signaling is still in its infancy; and it is always true that in a new art those who practice it are prone to rush into details before establishing the sound underlying principles that should govern practice.

I am not attempting herein to describe signaling apparatus of any type, nor to suggest the form, color, position or motion to be used for any particular signal-aspect, nor the aspect to be employed to give any particular indication. It has been my intention simply to indicate some of the basic conditions that underlie the control of traffic of all kinds in the hope of stimulating an interest on the part of those concerned in highway traffic, in the study of the history of traffic control and the development of the art of signaling. We can never build a stable structure except upon a sound foundation.—From an address by Azel Ames before the American Automobile Association, at Jacksonville, Fla.

Applicants *for* Membership

The applications for membership received between March 15 and April 14, 1923, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, J. A., student, University of Minnesota, *Minneapolis.*

ARATA, L. D., student, University of Cincinnati, *Cincinnati.*

ARGELAN, PETER ARTHUR, student, University of Cincinnati, *Cincinnati.*

BECK, MILTON, chief engineer, Stanley Motor Carriage Co., *Newton, Mass.*

BERSIE, HUGH G., engineer, Haskelite Mfg. Corporation, *Chicago.*

BIRD, LEON F., student, University of Cincinnati, *Cincinnati.*

BOLGER, JOHN F., vice-president, Allbestos Corporation, *Logan, Philadelphia, Pa.*

BOYD, PAUL M., student, University of Minnesota, *Minneapolis.*

BRIER, ALBERT T., instructor of auto mechanics, Elwood Public Schools, *Elwood, Ind.*

BUCHANAN, ALEXANDER D., student, University of Michigan, *Ann Arbor, Mich.*

BURNS, CHARLES E., JR., mechanical laboratory assistant, Bureau of Public Roads, *City of Washington.*

COLLIER, J. F., manager service, Reo Motor Car Co., *Lansing, Mich.*

COLE, WHEELER J., student Tri-State College, *Angola, Ind.*

CONE, LOGAN J., student, University of Cincinnati, *Cincinnati.*

COWAN, GERALD A., student, University of Cincinnati, *Cincinnati.*

CRABTREE, L. B., student, University of Cincinnati, *Cincinnati.*

CRAFT, EDWARD B., chief engineer, Western Electric Co., *New York City.*

CRAIN, ALLAN MEYER, student, University of Cincinnati, *Cincinnati.*

DAVIS, J. B., production manager, Standard Textile Products Co., *New York City.*

DAVIS, LEWIS K., managing director, Roadless Patents Holding Co., *City of Washington.*

DEBRUL, WILLIAM E., student, University of Cincinnati, *Cincinnati.*

DIBBLEE, WALTER AUGUSTUS, JR., student, University of Cincinnati, *Cincinnati.*

DODS, JOHN P., vice-president, Brightman Mfg. Co., *Columbus, Ohio.*

DUNHAM, TAYLOR H., student, University of Cincinnati, *Cincinnati.*

DURHAM, PERCY J., president and general manager, P. J. Durham Co., *New York City.*

EBERHARDT, FRED ROSS, manager gear department, Newark Gear Cutting Machine Co., *Newark, N. J.*

EXLEY, LUCIUS M., student, University of Cincinnati, *Cincinnati.*

FABER, L. E., mechanic, Yellow Cab Mfg. Co., *Chicago.*

FREEMAN, F. P., superintendent of motor equipment, Kaufman's Department Stores, Inc., *Pittsburgh.*

FREY, ARWIN P., student, University of Cincinnati, *Cincinnati.*

FRIESTADT, MORTIMER, chief mechanic, H & C Auto Repair Co., *Brooklyn, N. Y.*

GAGE, N. E., sales manager, National Tool Co., *Cleveland.*

GANTES, RAMON, mechanical engineer, Chilian Consulate, *New York City.*

GIALDINI, B. THOMAS, student, University of Cincinnati, *Cincinnati.*

GILBERTSON, GEORGE B., student, University of Minnesota, *Minneapolis.*

GLYNN, FREDERICK K., engineer of motor vehicles, New York Telephone Co., *New York City.*

HUKILL, H. D., in charge of automotive division, Westinghouse Air Brake Co., *Wilmerding, Pa.*

HULTON, RALPH, branch manager, Lovejoy Detroit Co., *Detroit.*

IRISH, L. A., manager, New York Yellow Cab Co., Sales Agency, Inc., *New York City.*

KIZER, KARL K., president, Kizer Equipment Co., *Chicago.*

LONTZ, DUDLEY M., student, University of Cincinnati, *Cincinnati.*

MCVEIGH, LUKE M., student, Cornell University, *Ithaca, N. Y.*

MACKENZIE, ROBERT E., advertising manager, Timken Roller Bearing Co., *Canton, Ohio.*

MACMILLAN, R. D., director of sales and service, Albert Frank & Co., *New York City.*

MEAD, RICHARD O., sales manager, American Wood Rim Co., *Onaway, Mich.*

MEYER, HENRY F., truck equipment engineer, Van Dorn Iron Works, *Cleveland.*

MORAN, RONALD JAMES, student, Tri-State College of Engineering, *Angola, Ind.*

MUELLER, J. WESLEY, student, University of Cincinnati, *Cincinnati.*

NEVIN, CHARLES A., layout draftsman, L. W. F. Engineering Co., *College Point, N. Y.*

NOELKE, H. M., experimental assistant, International Motor Co., *New York City.*

NORTON, BENJAMIN M., sales manager, Four Wheel Hydraulic Brake Division, U. S. E. Corp., *New York City.*

OGAWA, YOSHIO, student, Tri-State College, *Angola, Ind.*

OSTBY, OSCAR F., general sales manager, Prest-O-Lite Co., Inc., *Indianapolis.*

PATON, CLYDE R., teaching assistant in mechanical engineering, University of Michigan, *Ann Arbor, Mich.*

PATTERSON, H. R., chief engineer, DeJon Electric Corporation, *Poughkeepsie, N. Y.*

PIETZ, LOUIS F., road engineer, International Harvester Co., *Sioux City, Iowa.*

SCHMID, WILLIAM A., JR., student, University of Cincinnati, *Cincinnati.*

SCHREINER, EDWARD, student, University of Cincinnati, *Cincinnati.*

SCHWEITZER, GEORGE A., student, University of Cincinnati, *Cincinnati.*

SMELLIE, DONALD G., assistant engineer, Holmes Automobile Co., *Canton, Ohio.*

TACKENBERG, RICHARD CHARLES, student, University of Cincinnati, *Cincinnati.*

TAYLOR, WILLIAM WHITWORTH, student, University of Cincinnati, *Cincinnati.*

THIERSCH, WALTER, student, University of Cincinnati, *Cincinnati.*

TITUS, CURTIS TURNER, student, University of Cincinnati, *Cincinnati.*

TOWNSEND, ARTHUR L., instructor in mechanical engineering, Massachusetts Institute of Technology, *Cambridge, Mass.*

TRIESLER, A. WAGER, student, University of Cincinnati, *Cincinnati.*

TYLER, DONALD WILSON, student, University of Cincinnati, *Cincinnati.*

VINCENT, FIRST-LIEUT., THOMAS K., Ordnance Department, Raritan Arsenal, *Metuchen, N. J.*

WAGNER, JOHN WESLEY, student, University of Minnesota, *Minneapolis.*

WAITE, GORDON TARBELL, student, University of Michigan, *Ann Arbor, Mich.*

WASMER, CLARENCE T., student, University of Cincinnati, *Cincinnati.*

WATSON, CLIFFORD E., student, Pratt Institute, *Brooklyn, N. Y.*

WILLIAMS, S. M., branch manager, Autocar Sales & Service Co., *New York City.*

WILSON, HARLAND D., chief chemist and chemical engineer, Prest-O-Lite Co., Inc., *Indianapolis.*

WILSON, J. F., body engineer, Chevrolet Motor Co., *Detroit.*

WOODHULL, J. R., student, University of Cincinnati, *Cincinnati.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between March 10 and April 10, 1923. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

CADENHEAD, GEORGE L. (E S) student, University of Illinois, Urbana, Ill., (mail) 311 East Green Street, *Champaign, Ill.*

DUBRUL, WILLIAM E. (E S) student, University of Cincinnati, *Cincinnati,* (mail) 835 Beecher Street.

DYMENT, ALBERT ELLIOTT (J) sales engineer, Goulds Mfg. Co., Seneca Falls, N. Y., (mail) 12 South Clinton Street, *Chicago.*

ECKERT, O. E. (M) lubrication engineer, Transcontinental Oil Co., Benedum-Trees Building, *Pittsburgh.*

FISHER, R. B. (J) student engineer, H. H. Franklin Mfg. Co., *Syracuse, N. Y.,* (mail) 327 South Avenue.

GRASS, ALBURN ROGERS (E S) student, University of Cincinnati, *Cincinnati,* (mail) 2338 Stratford Avenue.

GROSS, C. (A) service manager, Welbon Dayton Motor Car Co., *Dayton, Ohio,* (mail) 724 Idaho Avenue.

GROSSER, NELSON C. (A) service engineer, B. Robinson Supplies Ltd., *Moose Jaw, Sask.,* Canada.

HAMILTON, GEOFFREY JOHN (E S) student, Cornell University, *Ithaca, N. Y.,* (mail) 109 Cayuga Heights Road.

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KENZIE, LAURENCE FYFE (A) manager of sales, Eastern Division, automotive department, Dahlstrom Metallic Door Co., 305 Bulletin Building, *Philadelphia.*

KEISER, KARL W. (E S) student, University of Minnesota, Minneapolis, (mail) 1148 Churchill Avenue, *St. Paul, Minn.*

KUEN, E. A. (A) vice-president and engineer, Thomas J. Corcoran Lamp Co., *Cincinnati,* (mail) 4900 Spring Grove Avenue.

LEWELLEN, A. R. (M) electrical engineer, Chevrolet Motor Co., *Detroit.*

MINERS, M. VERNE T. (E S) student, University of Illinois, *Urbana, Ill.,* (mail) 107 East Chalmers Street.

MONTANYA, H. L. (A) chief inspector, Yard-O-Meter Corporation, 325 Locust Street, *St. Louis.*

OSMOND, CHARLES H. (A) chemical engineer, Atlantic Refining Co., *Philadelphia,* (mail) 3141 Passyunk Avenue.

PECK, FRANK (A) superintendent, Iowa State Tractor and Automobile School, *Sioux City, Iowa,* (mail) 721 Nebraska Street.

PLEUTHNER, CHARLES (M) passenger-car engineer, Pierce-Arrow Motor Car Co., *Buffalo,* (mail) 51 Norway Park.

PRESBREY, OTIS FLAGG (M) instructor, Polytechnic Institute of Brooklyn, 99 Livingston Street, *Brooklyn, N. Y.*

PRICE, CHARLES S. (M) chief engineer, Bethlehem Spark Plug Co., *Bethlehem, Pa.,* (mail) 1213 Wood Street.

SAMPLE, SAM STEELE (E S) student, University of Illinois, Urbana, Ill., (mail) 404 East Daniel Street, *Champaign, Ill.*

SAWYER, GEORGE W. (A) Sinclair Refining Co., *Omaha, Neb.*

WALKER, GEORGE L. (A) assistant to president, R & V Motor Co., *East Moline, Ill.*

WALTER, CHARLES TAYLOR (J) experimental engineer, Swift & Co., Union Stock Yards, *Chicago.*

WALTON, F. L. (A) general sales manager, Union Switch & Signal Co., Swissvale, Pa., (mail) 802 Ross Avenue, *Wilkinsburg, Pa.*

WHEAT, E. F. (A) superintendent, Y. M. C. A., Ninth and Carr Street, *St. Louis.*

WOODHULL, J. R. (E S) student, University of Cincinnati, *Cincinnati,* (mail) 930 Morris Street.

WYZALEK, JOHN F. (M) metallurgist, Hyatt Roller Bearings division of the General Motors Corporation, Harrison, N. J., (mail) 162 Chestnut Street, *Kearny, N. J.*

ZAHOUR, R. L. (J) student, Case School of Applied Science, *Cleveland,* (mail) 12410 Castlewood Avenue.

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H. W. ALDEN, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

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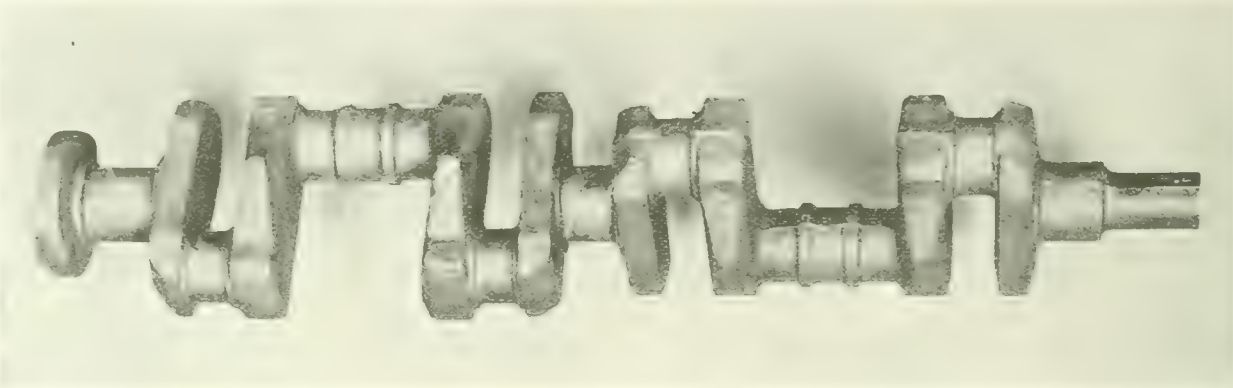
The Wyman-Gordon Crankshaft in the Duesenberg Straight Eight



which finished Sunday, April 29th, a fifty-hour twenty-one minute and one second non-stop 3155 mile run on the Indianapolis Motor Speedway at an average speed of 62.63 miles per hour, including three stops for tires.

Mr. Fred S. Duesenberg, Chief Engineer, writes, "The crankshaft certainly was in beautiful shape and none of the parts showed any wear from the effects of this run."

WYMAN-GORDON

The Crankshaft Makers

Worcester, Mass. Chicago, Ill. Cleveland, Ohio

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XII June, 1923 No. 6

Chronicle and Comment

Research Department Announcement

JOHN A. C. WARNER, formerly chief of the aeronautic instruments section of the Bureau of Standards, has been made Assistant Research Manager of the Society. The return of Dr. H. C. Dickinson to the Bureau of Standards after several months' extension of his leave of absence from that institution will not deprive the Research Department of his participation in its work. Arrangements have been made whereby he will be able to give a substantial amount of time to active work with the Research Department in New York City, in furtherance of the cooperative program between the Bureau of Standards and the automotive and the petroleum industries.

The general supervision of the work of the Research Department will not be changed; there will be no interruption of its activities in any particular, and we believe that with the continuance of the present hearty support of the membership the value of this Department will continue to grow at an increasing rate.

A Valuable Service

ENGINEERING publications, trade papers, laboratory reports, technical books and other valuable literature in the several branches of automotive engineering are received currently at the Society headquarters in New York City. This material comes from many sources, both foreign and domestic. It is studied with reasonable care by the members of the staff and the important articles or data are indexed in the reference files of the Research Department. For the benefit of THE JOURNAL readers it has been decided to carry these references currently in a section of THE JOURNAL in the future. The plan was started with the May issue and the members' attention is directed to p. 12 of the advertising section of that issue where many valuable references, abstracts and reviews will be found under the heading "Notes and Reviews". While this column is not represented as completely covering all automotive literature, it will be found to be fairly comprehensive, particularly in calling attention to matter that does not receive general circulation.

Members will be assisted in procuring copies of any of the original material referred to in Notes and Reviews. They are encouraged also to bring valuable articles or reports to the attention of the Research Department for mention in this new department. Notes and Reviews for this month will be found starting on p. 10 of the advertising section.

Division Reports

THE regulations of the Standards Committee provide that all recommendations approved by Divisions of the Standards Committee shall be acted upon at regular or special meetings of the Standards Committee. In the case of the Division reports printed on pp. 565 to 585 inclusive of this issue, the Standards Committee will act upon them during the first day of the Summer Meeting at Spring Lake this month.

Although the reports as approved by the Standards Committee must be confirmed by the Council, at the Society Business Meeting and by the voting members of the Society by letter ballot, the Standards Committee Meeting presents the last practical opportunity for Society members or non-members, who are of the opinion that the recommendations do not meet the requirements of the industry, to submit evidence, in person or in writing, supporting their opinions. In reading the reports in this issue, it should therefore be borne in mind that the recommendations are tentative and may receive extensive revision or may even be referred back to the Divisions submitting them for further study.

Elimination of Waste Effort

THE following statement is quoted from a letter received by the Society in answer to a general inquiry, which had been sent to passenger-car body builders and passenger-car companies constructing bodies, requesting comments on a tentative recommendation on aluminum molding submitted by a Subdivision of the Passenger-Car Body Division.

> It is to be regretted that the automobile industry has not realized long before this time the enormous amount of waste effort caused by the unnecessary lack of standards in so many of the minor parts that enter into the construction of the finished car, and it is with great satisfaction that we note the efforts of the Society toward standardization.
>
> Although the work of the Passenger-Car Body Division on the formulation of body standards is progressing slowly, it is believed that the work is on a sound

basis and the executives of body and passenger-car manufacturers should make it possible for their companies to realize the economic benefits which may be gained through the adoption of the standards in future practice.

The Summer Meeting

THE arrival of the month of June ushers in the popular Summer Meeting of the Society. Spring Lake, N. J., has been chosen as the site of the 1923 meeting. Located on the Atlantic seashore and boasting of two fine resort hotels and unusually complete sports facilities, Spring Lake provides an appropriate setting for a successful assembly of the industry's engineering executives. The technical activities will concentrate on four outstanding topics: four-wheel brakes, large-section air-cushion tires, head-lamp glare, and fuel volatility in relation to crankcase-oil dilution. Instructive demonstrations form an important part of each of the sessions. Railroad fares have been reduced for this occasion and special trains will carry the members direct to Spring Lake without change. Further details are given on p. 617 of this issue of THE JOURNAL and last-minute announcements will reach the members in the Meetings Bulletin about June 5. Reservations of hotel accommodations should be made promptly through the New York City office of the Society. The number of reservations at the time of this issue of THE JOURNAL going to press had reached 631.

Nominating Society Officers

THE nomination of a group of Members to serve as officers of the Society in 1924 will probably be completed and announced at the Summer Meeting by the Nominating Committee of the Society. This committee consists of Members elected by the sections, each Section naming one man and an alternate, and three Members of the Society elected at the business session of the Summer Meeting. There being 11 Sections, the Nominating Committee will have 14 members at Spring Lake. The following have been named for service on the 1923 Committee by the Sections:

Section	*Member*	*Alternate*
Buffalo	E. T. Mathewson	
Cleveland	Ernest Wooler	O. A. Parker
Dayton	Lester Keilholtz	V. G. Apple
Detroit	G. E. Goddard	C. S. Whitney
Indiana	O. C. Berry	
Metropolitan	C. F. Scott	C. T. Myers
Mid-West	T. Milton	R. E. Wilson
Minneapolis	A. W. Scarratt	
New England	V. A. Nielsen	Ira D. Shaw
Pennsylvania	W. M. Newkirk	
Washington	A. W. S. Herrington	

The three members-at-large will be elected at Spring Lake on Tuesday evening, June 19; no two of them can reside in the same Section district.

Intelligence Tests

IN connection with articles on intelligence tests that have appeared in THE JOURNAL, some observations made by E. McCullough as follows are of interest. Gumption, that quality that keeps a man going, is twice as valuable as special training. Some psychologists say that it is impossible to improve the intelligence. The average man believes otherwise. He believes that no psychologist can measure intelligence; that the thing which is measured is only that part of the intellect which reasons. The so-called "intelligence" should be termed mental acumen. There are not many dull persons but there are many who take in ideas slowly. Persistence and ambition count for much. Many quick-thinking men do not always display great common-sense, while many slow-thinking and slow-acting men have a wonderful amount of it. Mental acumen plus education and experience form intelligence.

Society News

DURING the past few months there has been a gradual change in character and scope of certain pages of THE JOURNAL. An effort is being made to report the news of Society meetings and activities in a prompt, complete and interesting manner in the section of THE JOURNAL that follows the formal publication of papers and addresses. This part of THE JOURNAL, which may properly be termed the news section, takes on the character and make-up of the trade paper, and will report current meetings in a style that is easy to read and sets forth the principal engineering thoughts expressed at Society meetings. Use is made of the familiar form of news headline to enable the reader to select readily the matters of greatest interest to him. Illustrations will be used to supplement the printed story and lend more intimacy to the remarks of the speakers. The progress of the Standards Committee Divisions will be recorded in like style as will the actions of the Council and administrative committees.

The outstanding papers read before national and sectional meetings will continue to be published in complete form in the forward part of THE JOURNAL. It is believed that the news reports will appeal particularly to members engaged in non-technical or semi-technical work who may have found it difficult to study the formal technical papers to profit by the engineering information set forth in them. The news matter in this issue starts on p. 610.

Highways

THE State Highway Commission of Iowa has stated that the cost of paving a dirt road can be retired in 9 years by the saving in transportation costs; and that highway taxes, which are only 15 per cent of the total taxes, are responsible for only one-eighth of the total increase in taxes since 1910. Sound policies must be taught in the financing of roads, particularly as respects the relation of bonds to revenues from current fees. The discussion of highway finance is simplified when it can be shown that a given highway reduces the expenditure of a community, or adds to its productivity sufficiently to justify the undertaking. It must be the task of highway research to determine the facts.

The efforts of the highway engineer to build road surfaces have not kept pace with the growth of highway traffic that has arisen so recently and increased so rapidly in the United States. From 1910 to 1921 the investment in rolling-stock has been three times that in roadbeds of highways. No other country has taken up the task of furnishing highways for so large an area, some 3,000,000 square miles. Texas has 262,000, while France has only 212,000 square miles. After many years the Pennsylvania Railroad has completed a roadbed from Chicago to New York City, a distance of 900 miles, over which trains can be operated safely in 20 hours. In the State of Texas a single through-highway will cover an equal distance. Unless the highway program shall be halted by reaction, we face an annual expenditure of nearly $1,000,000,000 for road improvement, provided contractors, men, materials and transportation shall be available.—Dr. W. K. Hatt.

An Investigation of Some Heavy-Duty Truck Drive-Axles

By S. von Ammon[1]

Cleveland Automotive Transportation Meeting Paper *Illustrated with* Photographs and Charts

A RECORD of an investigation of heavy-duty truck-axles carried out by the Bureau of Standards at the request of the Motor Transport Division of the Quartermaster Corps, this paper deals in particular with the mechanical efficiency of the axles tested. The investigation included, in addition to several worm-drive Class-B Army-truck axles with different types of bearing, a number of axles usually designated respectively as "internal-gear" and "multiple-reduction" type. Each of these types was represented by axles in successful use in commercial trucks of 5-ton rating.

In analyzing the results of the tests it was found possible to separate the losses into no-load losses and load losses; the total loss being the sum of these two. In general, the no-load losses were primarily controlled by the viscosity and the method of application of the lubricant. They were greater in those axles in which the parts rotating at high speeds were immersed most completely in the lubricant. Where a separate body of lubricant was used in the wheels, the losses were increased still further. In a given axle, these losses also increased with an increase in the viscosity of the lubricant and with the propeller-shaft speeds.

The load losses, expressed as torque, were practically independent of the speed and of the viscosity and the method of application of the lubricant. They increased, however, with an increase of the torque input and at an increasing rate. In the case of the several Class-B worm-type axles tested, the increase in the load losses with an increased torque-input was greater than with any of the gear-type axles.

The use of a lubricant of lower viscosity at low temperatures would improve the mechanical efficiency under the more unfavorable conditions of speed and temperature and seems advisable. Such lubricant should, however, be no less efficient than that used in the tests at the higher temperatures and the heavy pressures resulting from high torque-values. Improvement in the method for circulating the lubricant is suggested as desirable by the results; the high no-load losses of some of these axles show the present method of circulation to be very inefficient. The characteristic difference between the worm-drive and gear-drive types is demonstrated by the greater load losses of the former type.

AN appreciation of the importance of securing more complete information than was available at the time, led the motor transport division of the Quartermaster Corps to request the Bureau of Standards in 1920 to undertake an investigation of the several types of rear axle suitable for heavy-duty trucks. This paper deals with some of the results of this investigation, having particular reference to the mechanical efficiency of the axles tested.

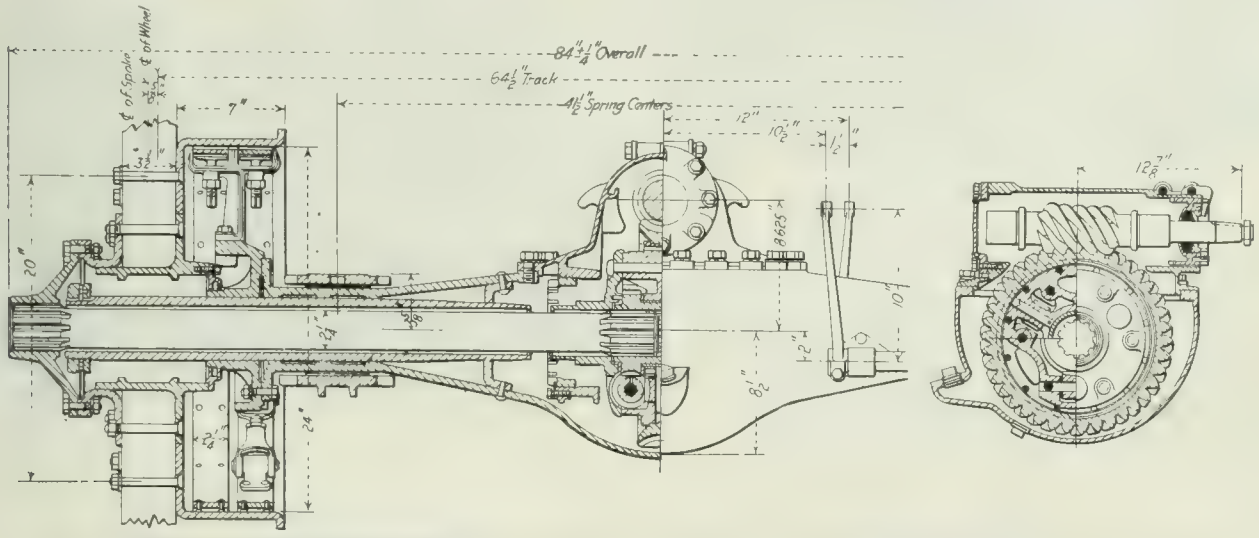


Fig. 1—Sectional View of the Class B Army Truck-Axle Equipped with Tapered Roller Bearings Throughout

The interest of the Motor Transport Division was centered largely upon the Class-B 3½ to 5-ton truck and, as a need for replacement axles for this truck was expected, those features and dimensions essential for this use were specified in an invitation issued to axle manufacturers to submit suitable axles. Of these features, the following are of interest here: (*a*) maximum torque-input 17,000 lb-in., (*b*) weight on spring-pads 12,000 lb., (*c*) minimum ground-clearance with 40-in. tires 11½ in., (*d*) maximum reduction-ratio 10.25, (*e*) minimum reduction-ratio 8.90, and (*f*) a non-locking differential. The maximum input-torque was based on 95 per cent of the maximum torque of the standard Class-B-truck engine between 400 to 1200 r.p.m., 3000 lb-in., reaching the axle through the 5.93 to 1 low-gear ratio of the standard Class-B transmission.

In response to the invitation, a number of sample axles

[1] Mechanical engineer, Bureau of Standards, City of Washington.

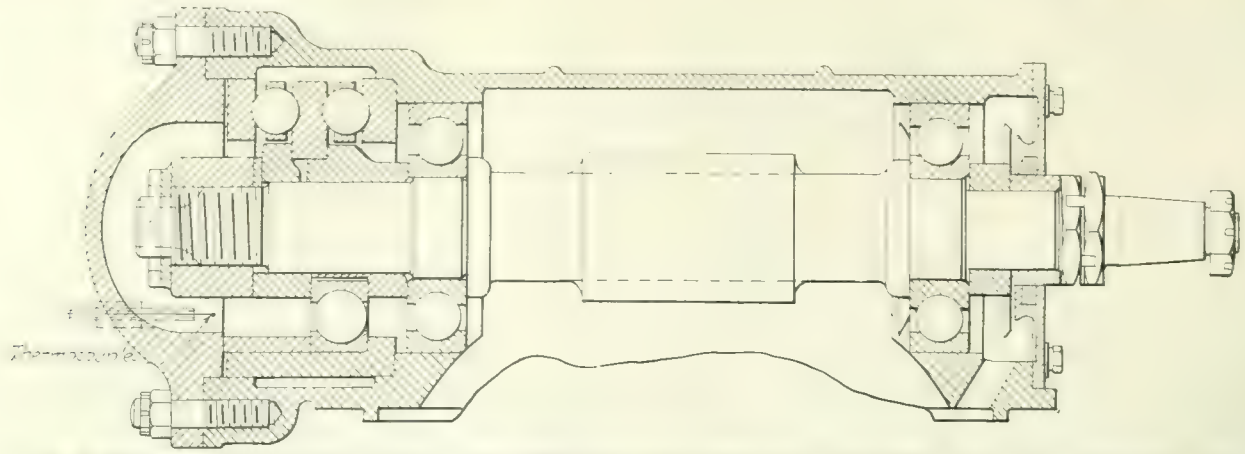


FIG. 2—SECTIONAL VIEW OF THE CLASS B ARMY TRUCK-AXLE EQUIPPED WITH SINGLE-ROW RADIAL BALL BEARINGS AND SHOWING THE LOCATION OF THE THERMOCOUPLE USED TO MEASURE THE LUBRICANT TEMPERATURES

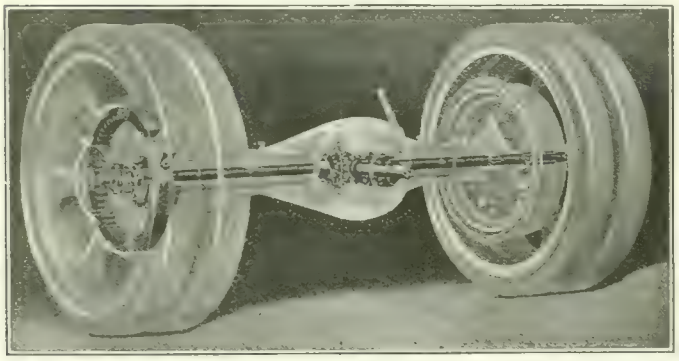


FIG. 3—PHANTOM VIEW OF THE THREE-STAGE DOUBLE-REDUCTION TYPE AXLE

of nominal 5-ton rating were sent to the Bureau of Standards. The investigation also included one 5-ton axle of the multiple-gear-drive type designed and used for lower input-torque; for this and other reasons, the manufacturer made it available for test neither with a view to its use in the Class-B standard truck nor any claim of its ability to meet the above specification. This axle, however, represents a distinct type in successful use, and the test results were therefore expected to be of general interest. The Motor Transport Division furnished a standard Class-B axle, and the necessary worm and differential assemblies for testing this axle with different types of bearing. The Bureau thus had available

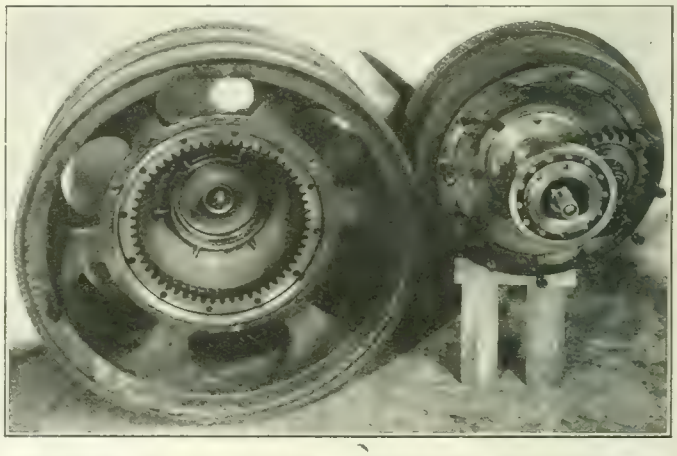


FIG. 4—VIEW OF THE THREE-STAGE DOUBLE-REDUCTION

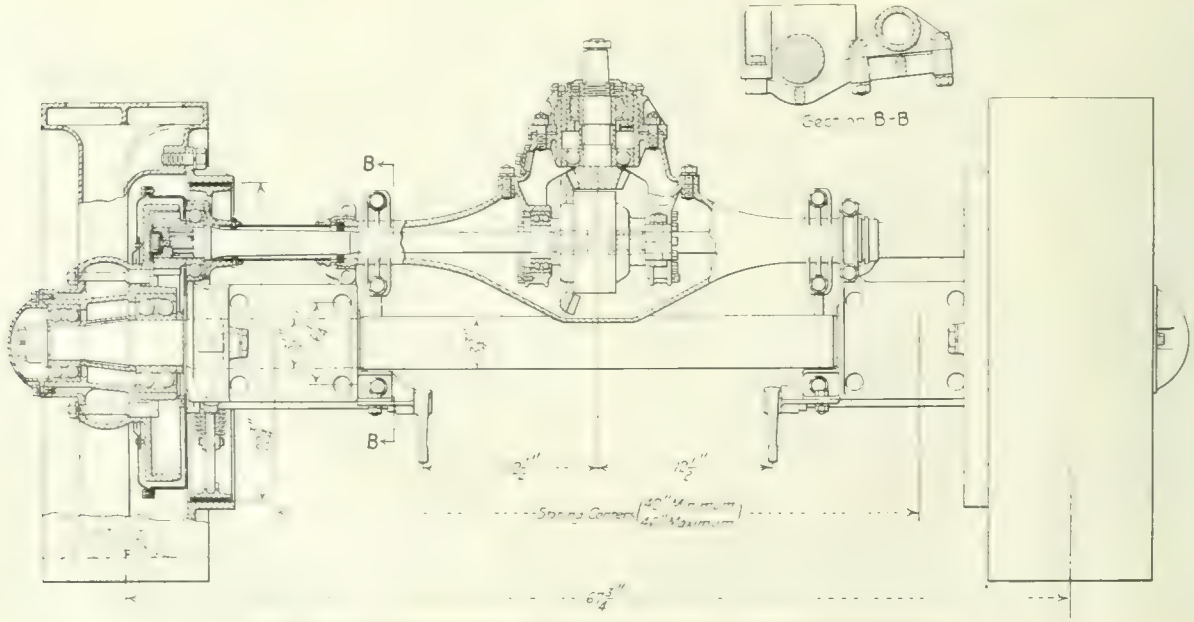


FIG. 5—AN INTERNAL GEAR TYPE AXLE HAVING A RATIO OF 9.605 TO 1

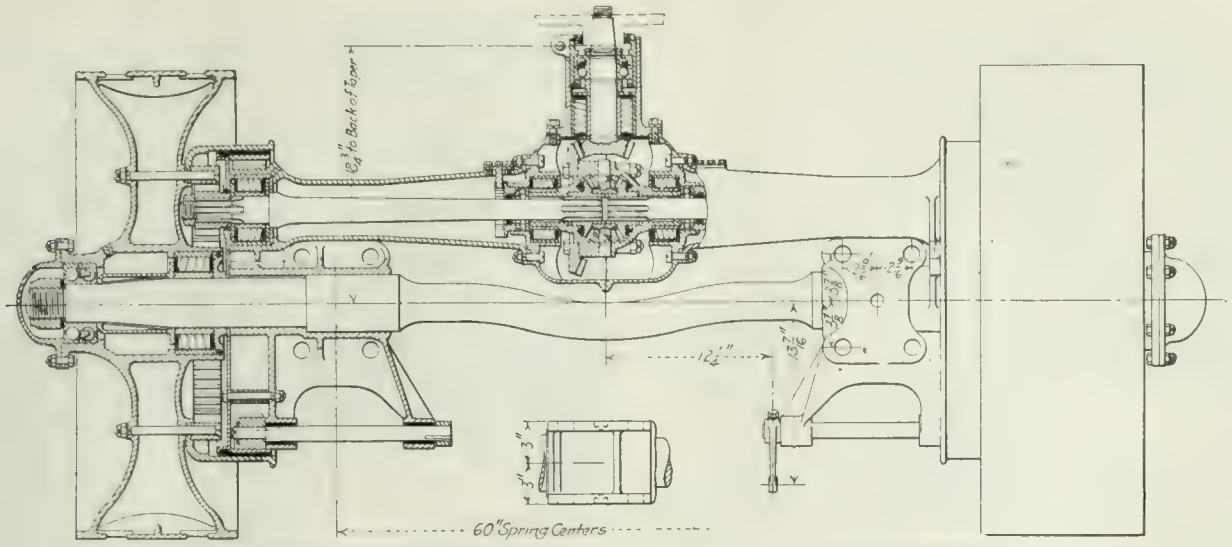


FIG. 6—ANOTHER INTERNAL-GEAR TYPE AXLE HAVING A RATIO OF 12.56 TO 1

for this investigation the following axles of a rated capacity of 5 tons. The same housing, wheel and wheel bearings were used in Axles *A*, *B* and *C*.

Axle A—Class-B Army truck-axle with tapered-roller bearings throughout; ratio 9.5 to 1; shown in Fig. 1.

Axle B—Class-B Army truck-axle with single-row radial ball-bearings and thrust washers for the worm and tapered-roller bearings for the differential; ratio 9.5 to 1; shown in Figs. 1 and 2.

Axle C—Class-B Army truck-axle with three single-row ball-bearings for the worm, one of these taking the thrust load only and the others the radial load only, and tapered-roller bearings for the differential; ratio 9.5 to 1; shown in Figs. 1 and 2.

Axle D—Three-stage double-reduction type; two stages in the wheels; ratio 11 2/3 to 1; shown in Figs. 3 and 4.

Axle E—The same axle as Axle D, but equipped with a bevel pinion and gear for a ratio of 13 1/3 to 1; shown in Figs. 3 and 4.

Axle F—An "internal-gear" type axle; ratio 9.605 to 1; shown in Fig. 5.

Axle G—An "internal-gear" type axle of another make; ratio 12.56 to 1; shown in Fig. 6.

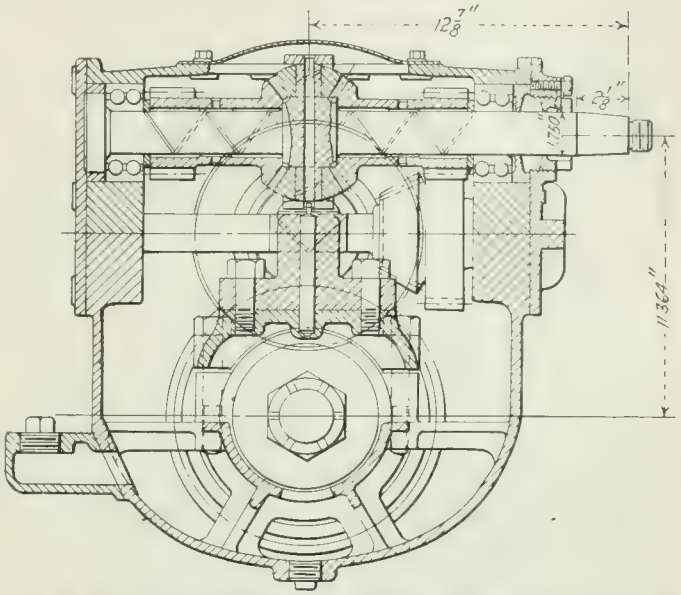


FIG. 8—ANOTHER VIEW OF THE TRIPLE-REDUCTION AXLE SHOWN IN FIG. 7

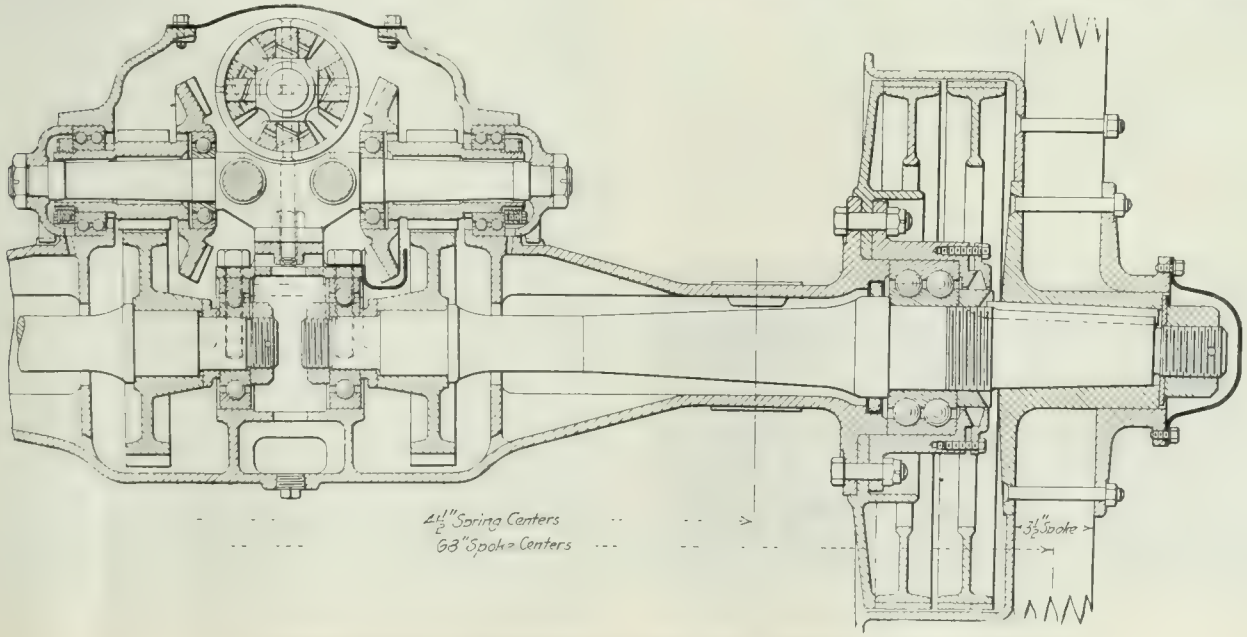


FIG. 7—VIEW OF THE TRIPLE-REDUCTION AXLE WITH ALL GEARS IN A CENTRAL HOUSING

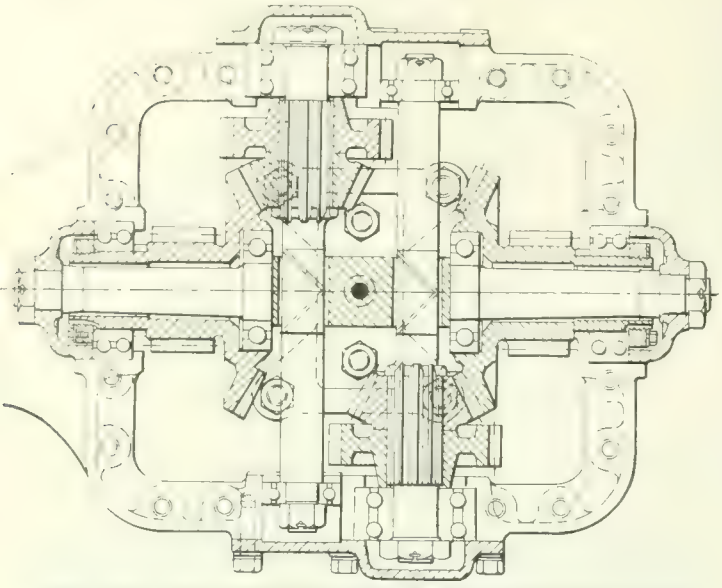


FIG. 9—A TRIPLE REDUCTION AXLE HAVING A RATIO OF 9.43 TO 1

Axle H—A "triple-reduction" type axle with all gears in a central housing; ratio 9.43 to 1; shown in Figs. 8 and 9.

Although the double-reduction type, with both reductions in the central housing, is in successful commercial use, it was not presented. Axles *D*, *E* and *G* are built only with the ratios stated, and manufacturers were unable to furnish bevel pinions and gears to bring the ratio within the range specified. The axles tested were all representative of their type and, with one exception, representative specimens of regular production.

TEST METHODS AND EQUIPMENT

The axle tests were carried out in the dynamometer laboratory of the automotive powerplants section of the Bureau of Standards with test equipment most of which was specially designed and constructed for the purpose as shown in Figs. 10, 11 and 12. An electric cradle-dynamometer of ample capacity used as a motor furnished the power. To obtain satisfactory and more economical operation at low propeller-shaft speeds, a standard Class-B Army-truck transmission was used between the dynamometer and the axles. The gear-ratios in this transmission are respectively 5.934, 3.237, 1.766 and 1 to 1.

The objectionable influence of the losses in the transmission varying with the speed, the load, the amount and the temperature of the lubricant and the condition of wear of the bearings and the gears was eliminated by rigidly connecting the case of the Class-B transmission

[1] See TRANSACTIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, vol. 40, p. 101.

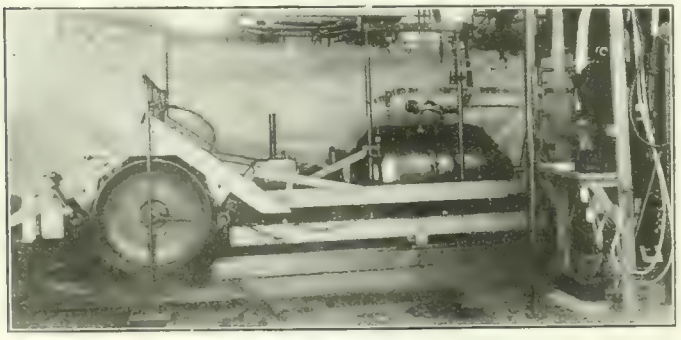


FIG. 10—SIDE VIEW OF THE APPARATUS WITH WHICH THE TESTS DESCRIBED IN THE PAPER WERE CONDUCTED

by stout braces to the field frame of the cradle dynamometer. A rigid coupling connected the transmission and the dynamometer shafts and the outer end of the transmission case was, because of the large overhang, given additional support in a ball bearing mounted on the floor-plate. A beam secured to the transmission case, as shown in Fig. 11, served for roughly balancing the case. The torque-arm of the dynamometer field-frame thus indicated the axle input-torque, regardless of the losses in the transmission. The balance of the dynamometer system was, however, measurably influenced by the quantity and the temperature of the oil in the transmission and the distribution of this oil as governed by the speed and the gear-ratios used. This could be and was taken care of by running the dynamometer and the transmission disconnected from the axle, before each test, at the speed and the gear-ratio to be used, and noting the zero position of the system for the particular set of conditions. Very close control of this factor was obtained by first bringing the temperature of the transmission oil to the operating temperature and again checking the zero position at the conclusion of each day or after each run with a given speed or gear-ratio.

The transmission main-shaft and the propeller-shaft of the test axle were connected by two flexible couplings joined by a very short shaft splined at both ends; ample flexibility and a means of readily disconnecting the axle resulted. The test axle was mounted on two steel I-beams secured on and overhanging the floor-plate and spaced so that the axles were supported under the spring-pads and secured by heavy bolts as shown in the illustrations. These I-beams extended past the dynamometer and carried at their far ends the weighing gear taking the reaction of the brake-arms. Prony brakes, substantially constructed of structural steel, were used to absorb the power. A uniform surface with the various types of wheel was obtained by mounting on them standard tire-rims as used with the 40 x 6-in. solid tires and, after securing these by pins and welding, machining them to a smooth surface. Each prony-brake was equipped with an upper and a lower pair of flexible steel brake-bands lined with standard brake-lining 5 in. wide. The tension on each brake was adjusted by one heavy bolt, and means were provided for adjusting and equalizing the loads on the different bands.

Some difficulty was experienced at first with the lubrication of these brakes; after several trials, however, graphite grease was found very satisfactory, provided the temperature of the brakes was kept within the limits shown by experience. Even then the small size of the brakes for the horsepower absorbed and the operating conditions required much skill for satisfactory continuous operation. The length of the brake-arms, more than 13 ft., combined with the design of the brakes, reduced any error that may have resulted from slight changes in the location of the brakes on the wheels during the tests. To keep the speed of the two wheels constant, the differentials were locked by filling them with a soft metal. Fig. 12 shows the cross-beams with the knife-edge supports by which the torque of the two brake-beams is added. To facilitate the power measurements, the method first proposed by C. M. Allen and F. W. Roys in their paper entitled Efficiency of Gear Drives,[2] was used. The principle of this method consists of the use of a differential beam for balancing the input-torque against the output-torque. The losses are balanced by an adjustable rider-weight, from the size and necessary displacement of which the transmission losses in the axle are computed.

Referring to Fig. 13, which is a diagrammatic sketch

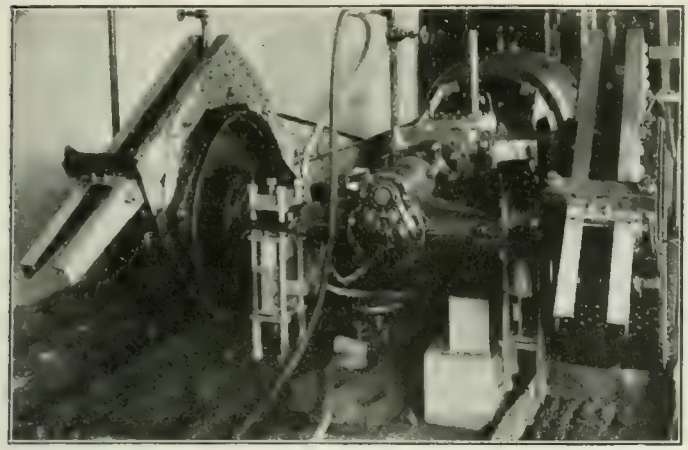


FIG. 11—END VIEW OF THE TEST APPARATUS SHOWING THE BEAM THAT WAS SECURED TO THE TRANSMISSION CASE TO ACT AS A ROUGH BALANCE

of the test equipment, the main knife-edge on the differential beam was carried in a separate block and its position could be altered readily to change the ratio of the two beam-ends as required by the varying reduction-ratios of the several axles. The differential beam was supported by the weigh-beam and, from the net indication of this, the input was calculated. Counterweights were provided at several points, and two simple oil dash-pots to dampen oscillations of the differential beam and the upper weigh-beam were located as shown. The heat generated at the brakes was absorbed by water fed into the hollow of the wheel rims, as shown in Fig. 10, a number of holes being provided for escape of the steam. A sprinkler over each wheel, fed by the overhead water-pipe shown in Fig. 11, served for the further control of the brake temperature. Two additional sprinklers, one above and one under the central housing, were used for cooling the sump and the bearings as required. The sump temperature was raised by a plumber's pot and several blow-torches, the flame of which was covered to prevent local overheating of the sump. The temperature of the lubricant was observed by thermocouples suitably located in the axle and the transmission. No particular difficulties have been met with in the control of the temperatures. The use of two brakes, as well as the utilizing of existing material and finally the flexibility required for testing the various types of axle, resulted in a rather large number of parts. The whole set-up, however, was well made and functioned well.

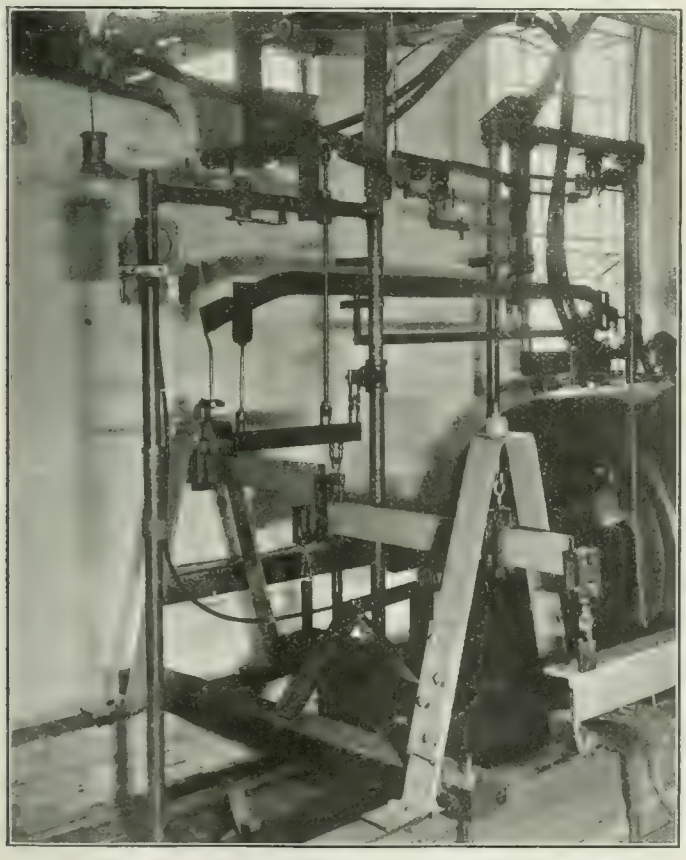


FIG. 12—THE CROSS-BEAMS WITH THE KNIFE-EDGE SUPPORTS BY WHICH THE TORQUE OF THE TWO BRAKE-BEAMS IS ADDED

TEST PROCEDURE

Each axle was given an initial inspection to insure the proper adjustment of the gears and, where possible, of the bearings and proper condition in general. The

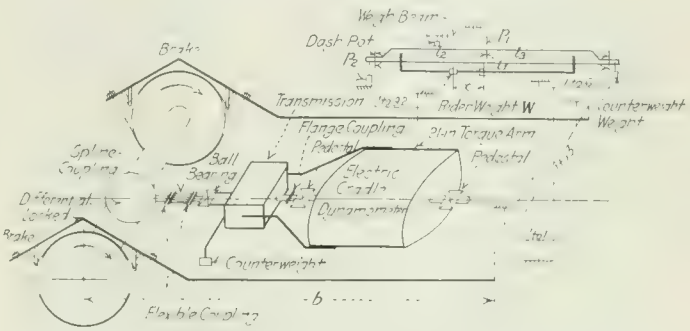


FIG. 13—DIAGRAMMATIC SKETCH OF THE TEST EQUIPMENT

standard brake-drum equipment was left on all axles during the tests; the brakes themselves were, however, removed to avoid any possibility of their rubbing on the drums. All thermocouples were projected reasonably far into the axle housing to assure their being immersed in the circulating oil. Each axle was run for a sufficient time to bed-in the bearings, the gears and the worm, to reduce as far as possible any changes in the mechanical fits during the tests. In these preliminary runs, the axles were run first with gradually increasing loads and then with loads up to about 50 hp. at a speed corresponding to about 8.5 m.p.h., and with oil temperatures ranging up to 100 deg. cent. (212 deg. fahr.). These preliminary runs aggregated several days and gave an opportunity to observe such changes in the losses as usually occurred during this period; the losses usually decreased somewhat at first. The best load conditions and period for running-in are somewhat difficult to determine. While a more severe load or a longer period might have improved some of the axles slightly, it might again have unfavorably affected some of the test results.

The efficiency tests were carried out at speeds corresponding as nearly as convenient to road speeds of 15.0, 12.5, 8.5, 4.5 and 2.5 m.p.h., based on 40-in. tires. To ascertain the influence of the viscosity of the lubricant on the losses, the efficiency tests were made at several oil-temperatures. With the first axle, these were respectively 40 and 80 deg. cent. (104 and 176 deg. fahr.). It was found, however, advisable and possible to extend this range and all other axles were tested at 40, 70 and 100 deg. cent. (104, 158 and 212 deg. fahr.) temperatures of the lubricant. The lowest of these figures, while considerably above the temperature at which the axles must operate at times, was very close to the minimum oil-

temperature that could be maintained with the cooling arrangements available. Many data could be gathered, however, at temperatures lower than 40 deg. cent. (104 deg. fahr.); for instance, during no-load tests and with light and medium loads at the beginning of a day's run. It thus became possible, from such data and by extrapolation, to secure with at least a very fair approximation the performance at the additional temperature of 20 deg. cent. (68 deg. fahr.). Even this by no means covers the conditions frequently met in winter operation. Two factors must, however, be kept in mind; first, that the viscosity of the lubricant used in the tests is very high at low temperatures and that it may therefore be advisable in such a case to use a lubricant of lower viscosity and, second, that in operation at low temperatures the losses will increase the temperature somewhat rapidly.

Reference is made here to a feature frequently noticed; it is that during the first period of a day's run when the oil temperature was low, the losses gradually decreased from a value higher than that corresponding to the same temperature when equilibrium was reached. The explanation of this is probably a higher lubricant-temperature between the working surfaces and a redistribution of the lubricant when equilibrium conditions have been reached.

An oil temperature of 100 deg. cent. (212 deg. fahr.) may seem excessive and beyond the range met in actual operation. A moment's consideration of the operating conditions in the Southwestern States, where air temperatures of 50 deg. cent. (122 deg. fahr.) or more are met, will, after making allowance for the temperature-rise that may readily result from unfavorable operating conditions, show that a lubricant temperature of 100 deg. cent. (212 deg. fahr.) is not only within the range of possibility, but may even be exceeded. The temperature-rise of the lubricant will, of course, depend on the magnitude of the losses, the outside temperature and the heat-dissipating capacity of the structure. Data on the temperature-rise at constant load were obtained by tests at high and at low speeds with a constant power transmission of about 50 hp.

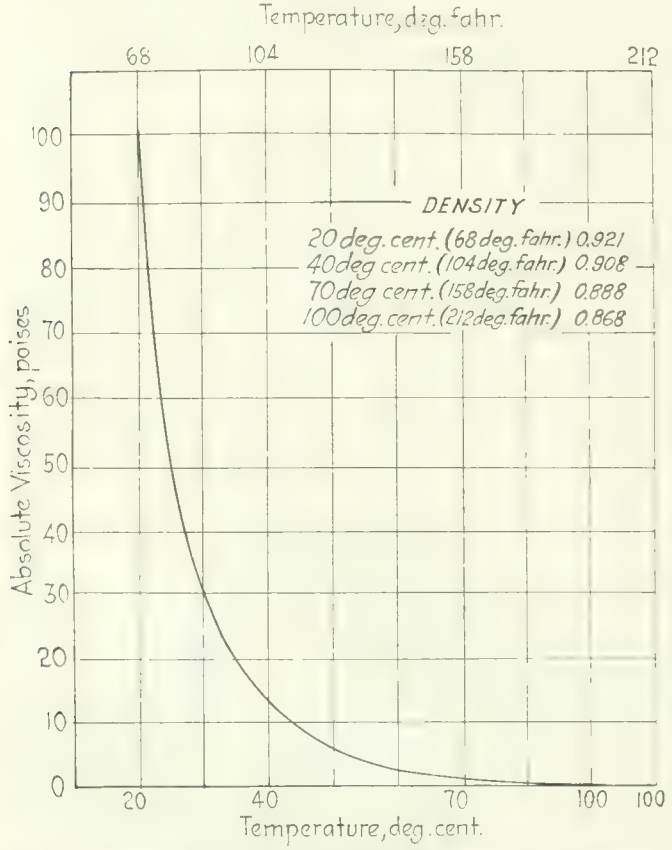


FIG. 11—CURVE SHOWING THE RELATION BETWEEN THE TEMPERATURE AND THE VISCOSITY OF THE TRANSMISSION LUBRICANT USED

In view of possible changes in the axle condition, it was found advisable to add tests to check the losses observed during the main tests; this was done for one lubricant-temperature at high and at low speed, as will be seen from the test program. Each axle was finally submitted to a low-speed test with high torque, at approximately 2.5 m.p.h., and this was designated as "endurance run" and continued in periods of 5 hr. daily until breakdown occurred or was clearly imminent. This run would perhaps be called more properly a "durability" run. It permits a fair estimate of the durability as regards both the mechanical wear and the efficiency of power transmission, these being related to each other. Owing to the differences in the ratios of the various axles, to the fact that the conditions of this test differ so much from what is met in actual service and for other reasons, the periods elapsing before breakdown occurred should not be taken as a direct measure of their relative endurance or capacity. They promised, however, to be of assistance in estimating to some extent the durability and to yield in addition data of value to the designer, not only in comparing the various axles with each other but in demonstrating the relative strength or durability of the various component parts of a given axle, particularly under severe service conditions. The information secured might thus point the way to improvement of the particular axle as a whole, by disclosing any weak links.

TEST PROGRAM

(1) Preliminary power-runs at 8.5 m.p.h. and at temperatures up to 100 deg. cent. (212 deg. fahr.).

(2) Efficiency tests; (*a*) at 8.5 m.p.h. and at temperatures of 40 and 70 deg. cent. (104 and 158 deg. fahr.); (*b*) at 12.5 m.p.h. and at 40 and 70 deg. cent. (104 and 158 deg. fahr.); (*c*) at 15.0 m.p.h. and at 40, 70 and 100 deg. cent. (104, 158 and 212 deg. fahr.); (*d*) at 4.5 m.p.h. and at 40 and 70 deg. cent. (104 and 158 deg. fahr.); (*e*) at 2.5 m.p.h. and at 40, 70 and 100 deg. cent. (104, 158 and 212 deg. fahr.); and (*f*) a short run at 1.7 m.p.h. and at 70 deg. cent. (158 deg. fahr.).

(3) A temperature-rise run at 15 m.p.h. with a constant load of about 50 hp.

(4) A check-run at 70 deg. cent. (158 deg. fahr.) and speeds of (*a*) 15 m.p.h. and (*b*) 2.5 m.p.h.

(5) No-load tests at several speeds and oil-temperatures.

(6) An "endurance" run at 2.5 m.p.h. with constant load of about 50 hp. with an observation of the temperature-rise in periods of about 5 hr. each day until breakdown occurred or was clearly imminent.

All speeds given in this program are in round figures; the actual speeds as shown in the records of each axle vary slightly with each axle-ratio. Various reasons causing departures from this general program are given in the Appendix. For any given speed, tests at the lower temperatures were usually made first, and the exceptions to this are shown. In all tests except the no-load tests, the minimum load was governed by and kept slightly in excess of that resulting from the weight of the brakes. In efficiency tests at a given speed and oil-temperature, readings were taken at from five to seven different loads ranging from this minimum to the maximum applied and were repeated at the same loads while descending.

The procedure was to set the weigh-beam, from which

the differential beam is suspended, to the figure representing the desired load; when, after correcting the brakes and the speed as required, the adjustment of the rider weight on the differential beam indicated a condition of equilibrium, the first reading was taken. After a 3-min. additional application of the same load, the second observation was made and the brakes were adjusted for the next load. During most of the tests, the intervals between the second reading at one load and the first reading at the next load, was 2 min. The maximum load was applied longer, so that at least three readings covering a period of 5 min. were obtained. The no-load tests were made during the latter part of the series to assure the axles being well run-in at the time. Test temperatures were controlled within a few degrees of the nominal figure. In some cases at low test-speeds, the indications of the thermocouples showed a slight lag.

Lubricant

Government-specification transmission-lubricant[3] was used in all of the axles tested and, to keep this strictly uniform throughout, the Motor Transport Division furnished the Bureau 1 bbl. of this material. The relation of the temperature to the viscosity of a sample of this oil is shown in Fig. 14. In view of the high viscosity at temperatures below 40 deg. cent. (104 deg. fahr.) and the difficulty of obtaining these with accuracy, this part of the curve must be taken as being approximate only.

[3] See Bureau of Mines Technical Paper No. 323, p. 25.

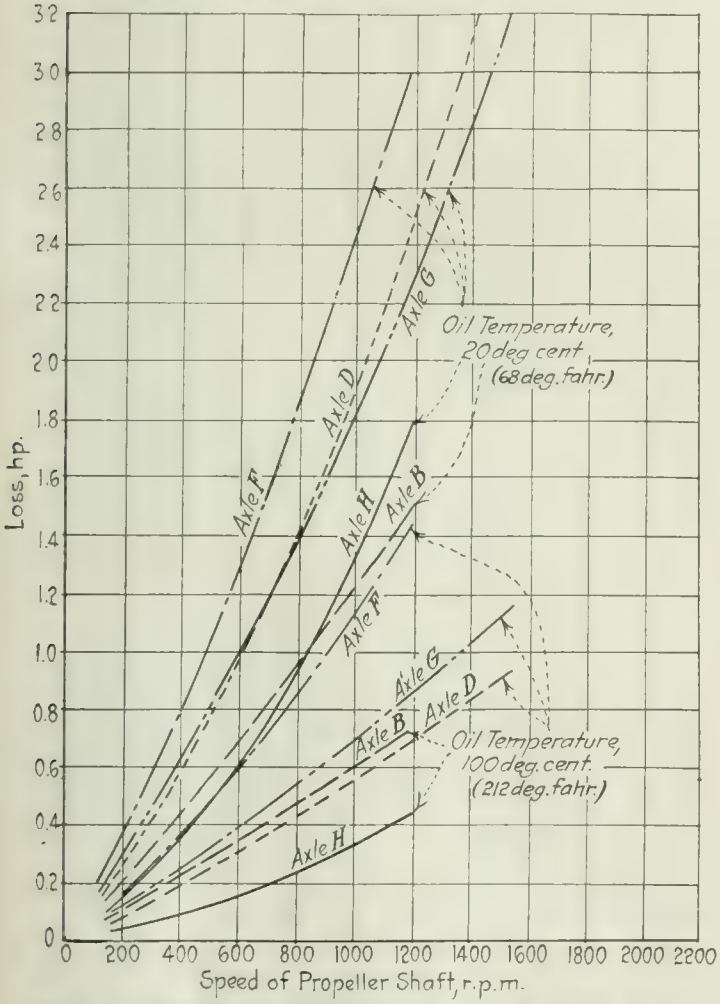


Fig. 15—Relation of the Maximum and Minimum No-Load Losses of the Axles to the Speed at Oil Temperatures of 20 and 100 Deg. Cent. (68 and 212 Deg. Fahr.)

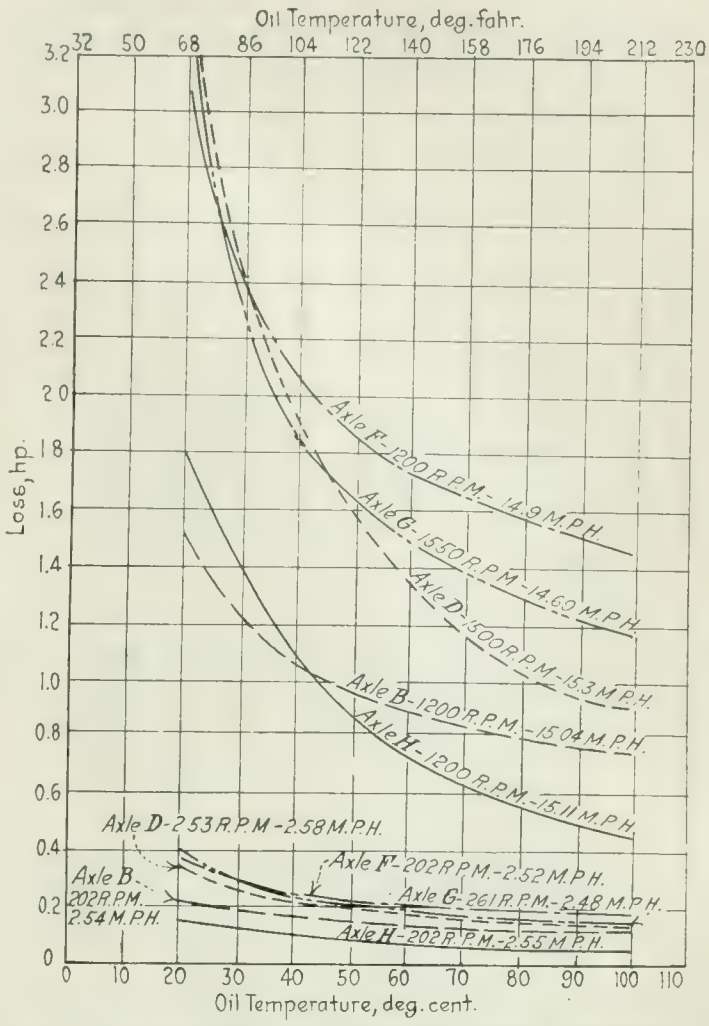


Fig. 16—The Maximum and Minimum No-Load Horsepower Losses Plotted Against the Oil Temperature at the Highest and the Lowest Speeds

The oil level in each axle was checked daily, and lubricant was added when necessary. As all tests were made with identical lubricant, the temperature of the latter is referred to throughout; it is of course understood that the corresponding viscosity of the lubricant and not the temperature governs the variation in the results, except as changes in temperature may affect fits and clearances.

Results

The test results have been analyzed to show the respective influence of power, torque, speed, temperature of the lubricant and no-load losses. The consistency of the results is better than was anticipated in view of the many factors affecting the behavior of an axle as a whole. The limited scope of this paper does not permit the presentation of all the data obtained with the axles tested. The data presented have, however, been selected with a view to demonstrating as clearly as possible the characteristic features of the types as shown by Axles *B*, *D*, *F*, *G* and *H*. Summaries of the results obtained in the tests of these five axles are plotted in Figs. 15 to 34.

In studying these results, it is well to consider the losses as made up of no-load losses and "load"-losses. The no-load losses consist of the power expended for the necessary circulating and unnecessary churning of the lubricant, the friction in the bearings and between the gear teeth when not transmitting useful load, the windage of the wheels and the brake-drums and a few smaller

items that need not be considered. The load losses are due to the useful power transmitted to the wheels, and result from the corresponding increase in the tooth and

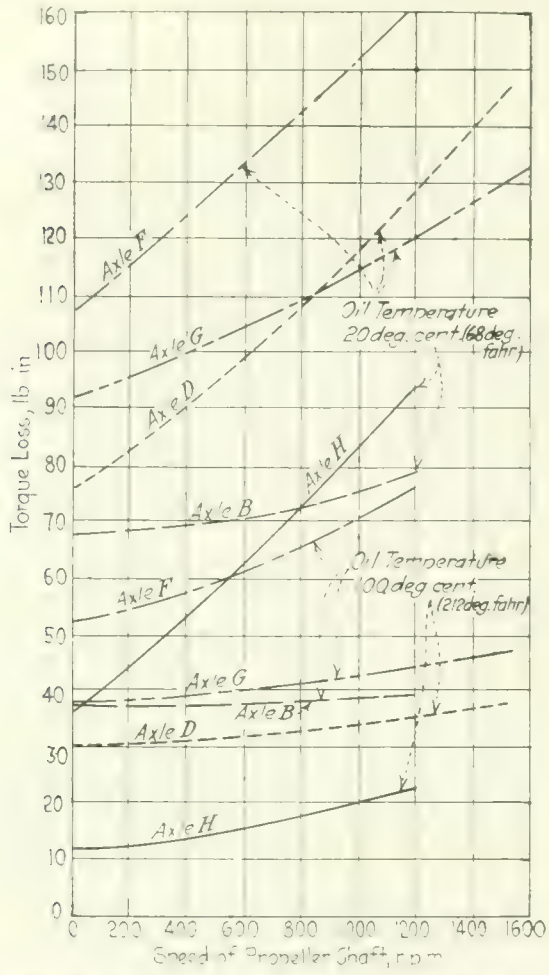

Torque Loss, lb in
Speed of Propeller Shaft, r p m
Axle F
Axle G
Axle D
Axle H
Axle B
Oil Temperature 20 deg. cent. (68 deg. fahr.)
Oil Temperature 100 deg. cent. (212 deg. fahr.)

Fig. 17—Relation between the Maximum and the Minimum No-Load Losses Expressed as Torque and the Speed at Oil Temperatures of 20 and 100 Deg. Cent. (68 and 212 Deg. Fahr.)

the bearing friction. The additional wheel-bearing losses resulting in road service under a truck and the increase in other bearing and gear losses that may result in such service could not be taken into account in this investigation. Such additions may, however, under unfavorable conditions become more marked with one or another axle.

The no-load losses are plotted in Figs. 15 and 16, and increase materially with increasing viscosity and speed. If, as plotted in Figs. 17 and 18, these losses are expressed as torque, we see that the increase is largely the result of the method of circulating the lubricant. At the high temperature, the torque loss increases but slightly with an increase in speed; on the other hand, a decreasing temperature results in an increase in these no-load losses in conformity with the rise in the viscosity.

Comparing the no-load losses in the different axles, for any speed or temperature at which the oil losses are of any moment, it is found that Axles *B* and *H* show lower values than Axles *D*, *F* and *G*. In Axle *B* the relatively slowly revolving worm-gear and differential and in Axle *H* the final spur-gears on the axle shafts are the only parts immersed in the sump pool in the central housing. This clearly accounts for the lower oil-losses compared with the other axles in which the bevel rings and the differentials rotate at much higher speeds, and the circulation of the lubricant in the wheels causes additional losses. The oil in the wheel would, at least at the higher speeds, tend to rotate with the wheel in a ring at the circumference of the internal-gear chamber. The end of the jackshaft with its pinion projects into this ring of oil of a high viscosity at low temperatures and prevents the orderly progress of the lubricant; the power loss thus occasioned may be smaller with grease if a part of the lubricant adheres to the wall of the chamber away from the pinion, as it may do, particularly at low temperatures. Additional obstructions in the wheel chamber as found in Axle *D* in the intermediate pinion and its supports may add to the losses. That the loss caused by the circulation of the lubricant in the wheel is considerable is clearly shown in the Appendix. The distribution of the lubricant in the central housing, as influenced by constructional features and speed and other smaller factors that need not be gone into here, may have an influence on the losses to be ascribed to the lubricant.

To obtain some data on the no-load losses, runs were made with Axle *H* with several oil-levels. The regular tests of this axle had been made with 3 gal. in the sump, this unusual amount being required because of the large volume of the housing. Fig. 19 shows the no-load losses as observed with 3 gal. of oil at four temperatures over the range of test speeds, as well as the losses at 20 deg. cent. (68 deg. fahr.) with varying amounts of oil. The dotted curve shows that the no-load losses without lubricant in the central housing were constantly higher than with 3 gal. of oil at 70 deg. cent. (158 deg. fahr.)

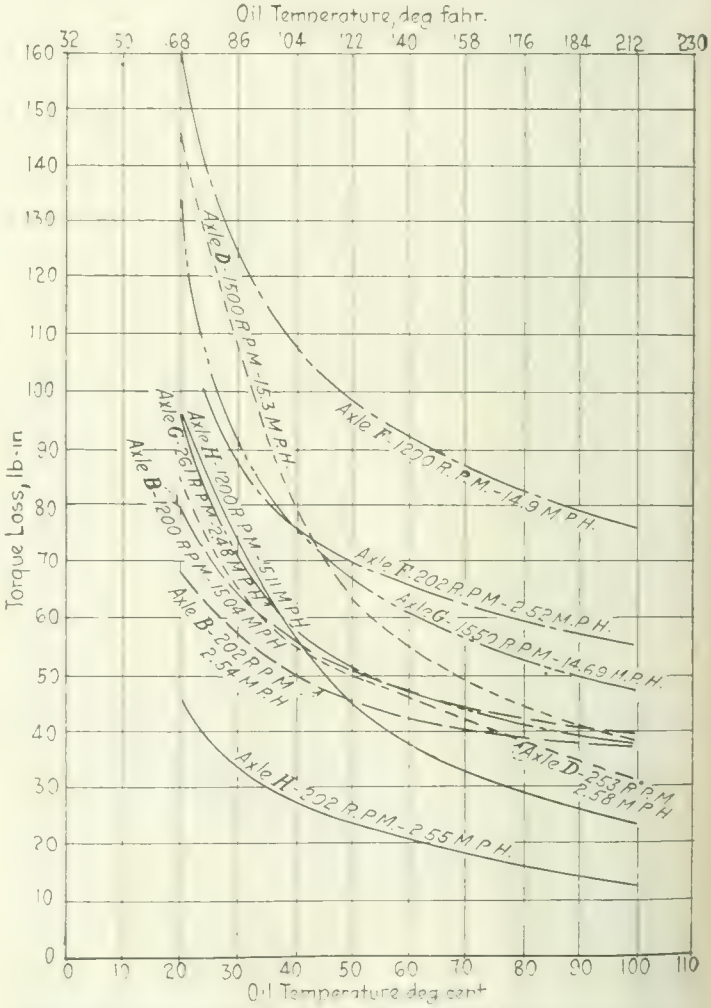


Fig. 18—The Maximum and the Minimum No-Load Losses Expressed as Torque Plotted Against the Oil Temperatures at the Highest and Lowest Speeds

A study of the load losses expressed as power shows that these increase with the power input and at an increasing rate. There is a fair similarity in the axles of the gear type, but the worm type shows a materially greater increase in these losses with an increasing input than any of the gear-type axles. The viscosity of the oil, however, has no influence on the load losses. These features can be seen readily in Fig. 20. Two apparent exceptions relating in Fig. 20 to Axle *B* are not fully understood. The observed values are slightly lower for 70 deg. cent. (158 deg. fahr.) than for either 40 or 100 deg. cent. (104 or 212 deg. fahr.). Further reference to this is made in the Appendix. The load losses in Fig. 20 also show an increased rate of growth with an increasing load and for a given power input with a decreasing speed.

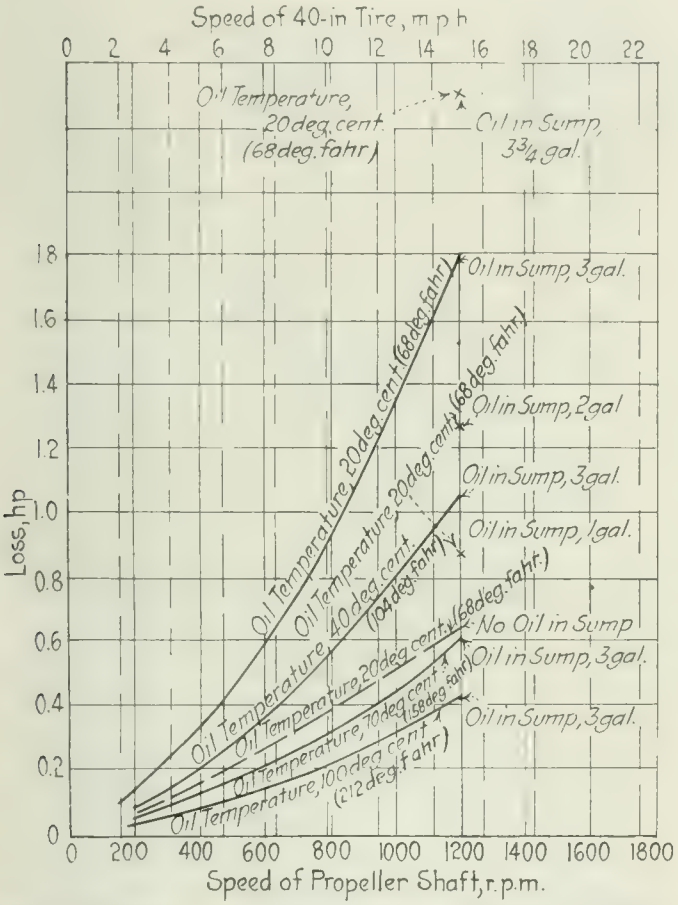

Speed of 40-in Tire, m p h
Oil Temperature, 20 deg. cent. (68 deg. fahr.)
Oil in Sump, 3¾ gal.
Oil in Sump, 3 gal.
Oil in Sump, 2 gal.
Oil in Sump, 1 gal.
No Oil in Sump
Oil Temperature, 40 deg. cent. (104 deg. fahr.)
Oil Temperature, 70 deg. cent. (158 deg. fahr.)
Oil Temperature, 100 deg. cent. (212 deg. fahr.)
Loss, hp
Speed of Propeller Shaft, r.p.m.

Fig. 19—Curves of the No-Load Losses at Different Propeller Shaft Speeds and Four Different Temperatures of the Lubricant

If the load losses expressed as torque are plotted against the torque input, we obtain Fig. 21 which shows clearly the similarity among the gear-type axles and the separate position of the worm type, in which these losses are not only greater over the whole range of the input torque, but increase more rapidly with an increasing torque. That neither the temperature nor the speed has any material influence on the load losses is clear from the fact that all points fall on or very close to the curves plotted. As the ratios of these axles differ, comparison on the basis of the torque input and loss is not entirely permissible. However, Fig. 21 shows the input torque, representing for each axle a wheel torque of 161,500 lb-in. when the losses in the axle are ignored. The corresponding torque-loss has been converted into a horsepower loss at a wheel speed of 2.5 m.p.h. in each case, thus establishing a better basis for comparison. The

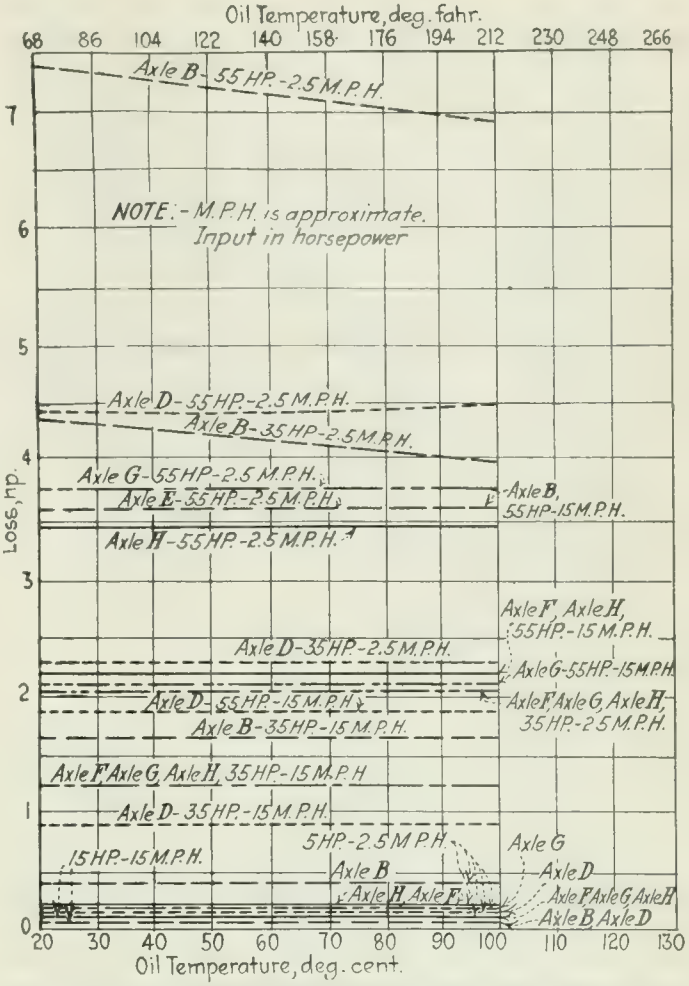

Oil Temperature, deg. fahr.
Axle B - 55 HP. - 2.5 M.P.H.
NOTE. - M.P.H. is approximate. Input in horsepower
Axle D - 55 HP. - 2.5 M.P.H.
Axle B - 35 HP. - 2.5 M.P.H.
Axle G - 55 HP. - 2.5 M.P.H.
Axle E - 55 HP. - 2.5 M.P.H.
Axle H - 55 HP. - 2.5 M.P.H.
Axle B, 55 HP. - 15 M.P.H.
Axle F, Axle H, 55 HP. - 15 M.P.H.
Axle D - 35 HP. - 2.5 M.P.H.
Axle G - 55 HP. - 15 M.P.H.
Axle D - 55 HP. - 15 M.P.H.
Axle F, Axle G, Axle H, 35 HP. - 2.5 M.P.H.
Axle B - 35 HP. - 15 M.P.H.
Axle F, Axle G, Axle H, 35 HP. - 15 M.P.H.
Axle D - 35 HP. - 15 M.P.H.
15 HP. - 15 M.P.H.
5 HP. - 2.5 M.P.H.
Axle G
Axle B
Axle D
Axle H, Axle F
Axle F, Axle G, Axle H
Axle B, Axle D
Loss, hp.
Oil Temperature, deg. cent.

Fig. 20—The Difference Between the Total and the No-Load Losses Plotted against the Oil Temperature with a Varying Horsepower Input at the Highest and the Lowest Speeds

total losses for the various axle types then represent the sum of these, widely and independently varying no-load and "load" losses.

Summaries of the total losses and the corresponding

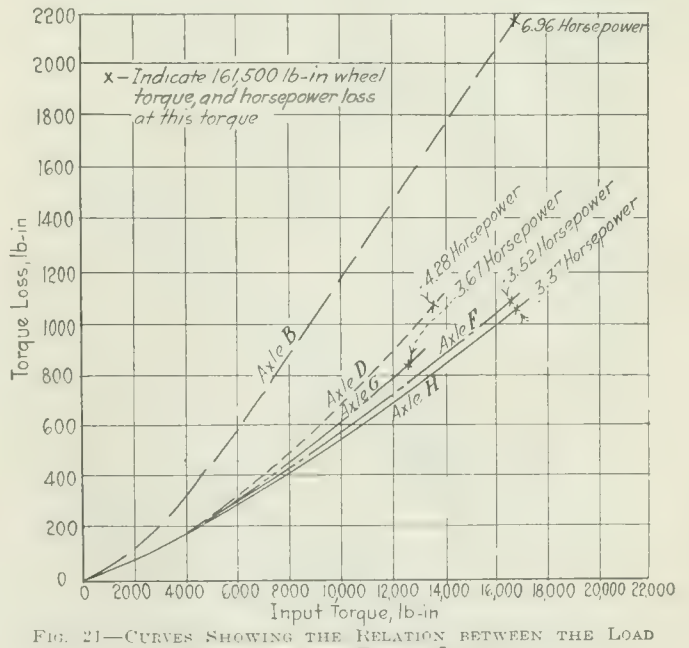


Fig. 21—Curves Showing the Relation between the Load Losses and the Torque Input

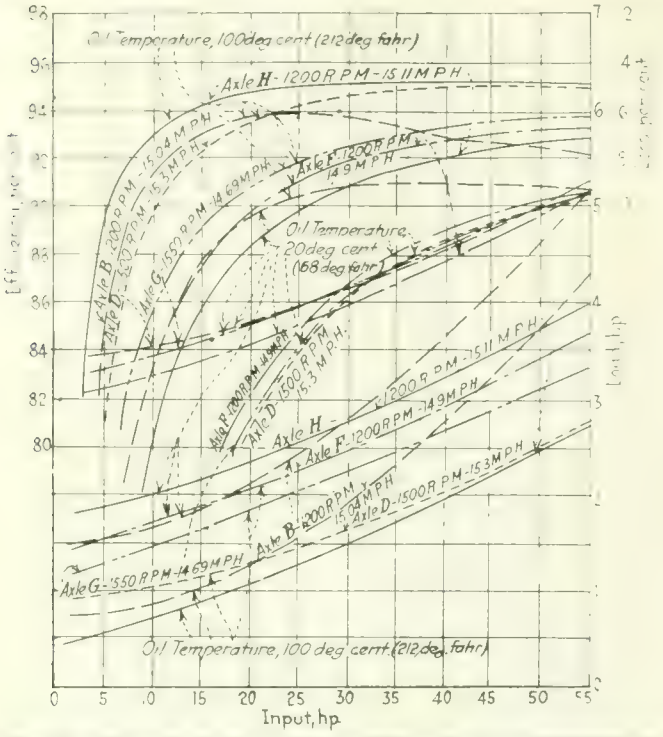

Oil Temperature, 100 deg cent (212 deg fahr)
Axle H-1200 R.P.M.-15.11 M.P.H.
Axle F-1200 R.P.M.-14.9 M.P.H.
Axle B-1200 R.P.M.-15.04 M.P.H.
Axle D-1500 R.P.M.-15.3 M.P.H.
Axle G-1550 R.P.M.-14.69 M.P.H.
Oil Temperature, 20 deg cent (68 deg fahr)
Efficiency, per cent
Loss, hp
Input, hp

FIG. 22.—SUMMARY OF THE TOTAL LOSSES AND THE CORRESPONDING EFFICIENCIES OF THE FIVE AXLES AT A SPEED OF 15 M.P.H. AND OIL TEMPERATURES OF 20 AND 100 DEG. CENT. (68 AND 212 DEG. FAHR.)

efficiencies for the five axles at 15.0 and at 2.5 m.p.h. are plotted in Figs. 22 and 23 respectively. The influence of the viscosity of the lubricant is greatest at high speeds and can be seen best in Fig. 22. The relation of the losses at high and at low speeds for the oil temperatures of 100 and 20 deg. cent. (212 and 68 deg. fahr.) is seen most readily in Figs. 24 and 25.

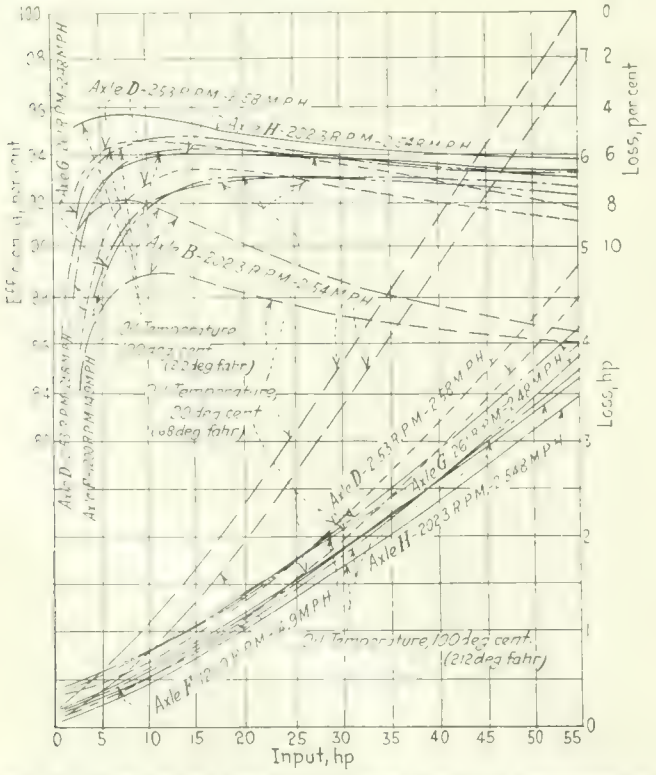


FIG. 23.—SUMMARY OF THE TOTAL LOSSES AND THE CORRESPONDING EFFICIENCIES OF THE FIVE AXLES AT A SPEED OF 2.5 M.P.H. AND OIL TEMPERATURES OF 20 AND 100 DEG. CENT. (68 AND 212 DEG. FAHR.)

The change in the total losses with the temperature for a 5 and a 55-hp. input at high and at low speed is plotted in Fig. 26. In Figs. 27 and 28, we have plots illustrating more conveniently the ratio between the total and the no-load losses and the influence of the speed on these losses and their relation to each other. The upper curve of each pair, as indicated, represents the total loss; the distance between the curves of a pair

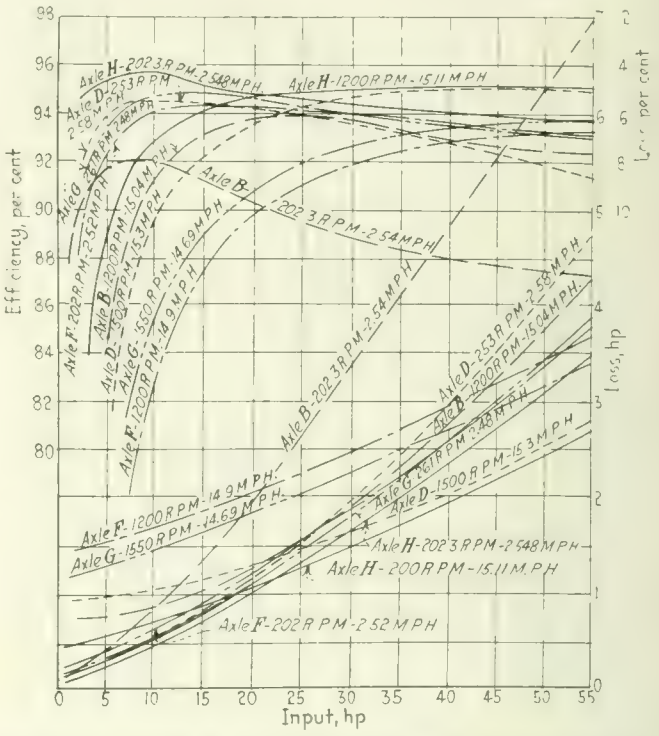


FIG. 24.—THE RELATION BETWEEN THE LOSSES AND THE EFFICIENCIES OF THE FIVE AXLES AT HIGH AND LOW SPEEDS AND AN OIL TEMPERATURE OF 100 DEG. CENT. (212 DEG. FAHR.)

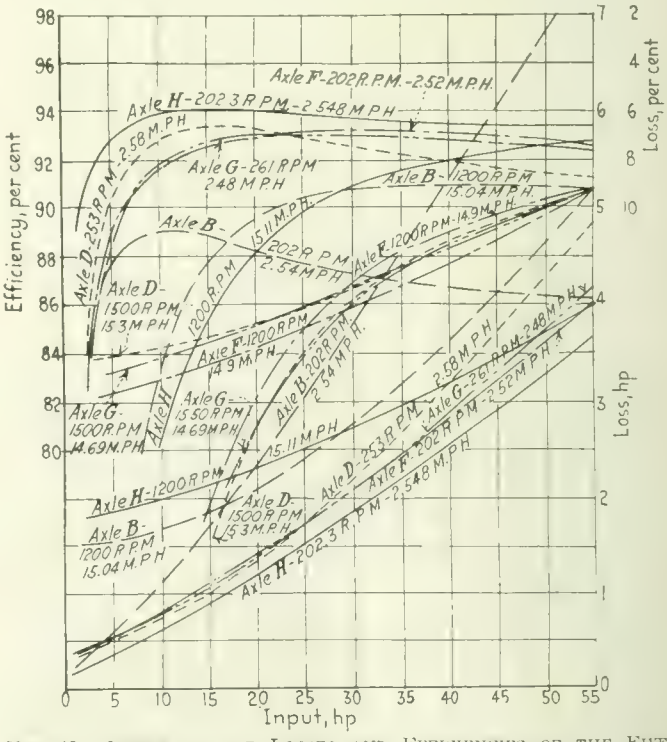


FIG. 25.—CURVES OF THE LOSSES AND EFFICIENCIES OF THE FIVE AXLES AT HIGH AND LOW SPEEDS AND AN OIL TEMPERATURE OF 20 DEG. CENT. (68 DEG. FAHR.)

shows the no-load loss. The changes in the losses due to the varying influence of the no-load and the load losses, as well as the preponderance of one or the other of these for varying speed and load, are found readily here; also, the wide differences as between axles and the very unsatisfactory balance that certain axles show in the relation of the no-load to the load losses.

In Fig. 29, each axle is represented by two curves showing the power loss as changing with the input torque, for high speed in conjunction with low temperature and for low speed with high temperature, respectively. For the axle covered, these curves are the limiting lines between which the values for all other combinations fall. The power loss for torque inputs of 500, 10,000 and 17,000 lb-in. as governed by the speed is

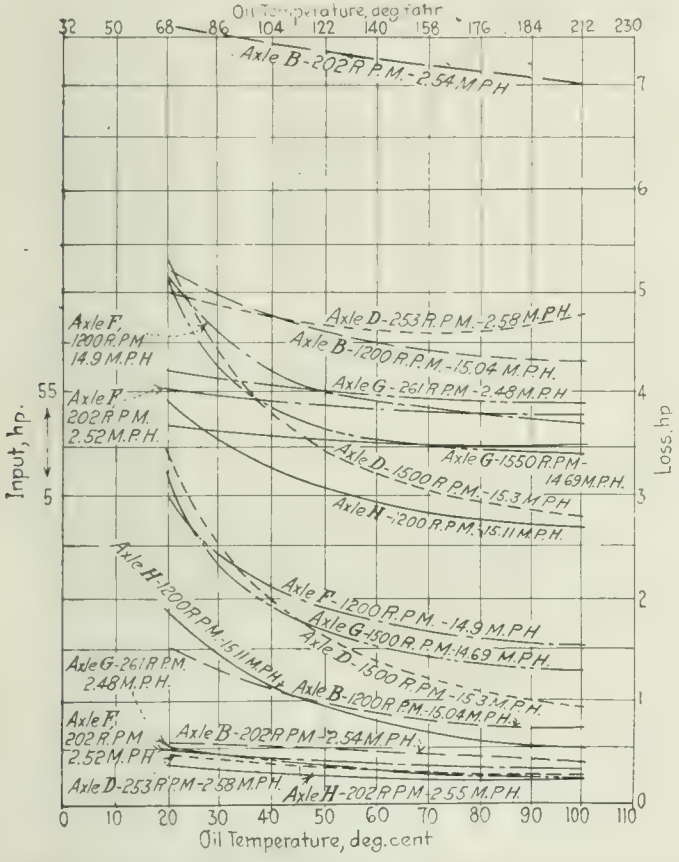

Oil Temperature, deg fahr
32 50 68 86 104 122 140 158 176 184 212 230
Axle B-202 R.P.M.-2.54 M.P.H.
Axle D-253 R.P.M.-2.58 M.P.H.
Axle B-1200 R.P.M.-15.04 M.P.H.
Axle G-261 R.P.M.-2.48 M.P.H.
Axle G-1550 R.P.M.-14.69 M.P.H.
Axle D-1500 R.P.M.-15.3 M.P.H.
Axle H-1200 R.P.M.-15.11 M.P.H.
Axle F, 1200 R.P.M. 14.9 M.P.H
Axle F, 202 R.P.M. 2.52 M.P.H.
Axle H-1200 R.P.M.-15.11 M.P.H.
Axle F-1200 R.P.M.-14.9 M.P.H
Axle G-1500 R.P.M.-14.69 M.P.H.
Axle D-1500 R.P.M.-15.3 M.P.H.
Axle G-261 R.P.M. 2.48 M.P.H.
Axle B-1200 R.P.M.-15.04 M.P.H.
Axle F, 202 R.P.M. 2.52 M.P.H.
Axle B-202 R.P.M.-2.54 M.P.H.
Axle D-253 R.P.M.-2.58 M.P.H.
Axle H-202 R.P.M.-2.55 M.P.H.
Input, hp.
Loss, hp.
55
5
0 10 20 30 40 50 60 70 80 90 100 110
Oil Temperature, deg.cent

FIG. 26—THE CHANGE IN THE TOTAL LOSSES FOR INPUTS OF 5 AND 55 HP. AT HIGH AND LOW SPEEDS PLOTTED AGAINST THE OIL TEMPERATURE

plotted in Fig. 30. The maximum and minimum losses and efficiencies for each axle, including all five test-speeds and temperatures of 20, 40, 70 and 100 deg. cent. (68, 104, 158 and 212 deg. fahr.), are plotted in Fig. 31. It is interesting to note here the similarity in losses and the range covered by the three axles with lubricant in the wheels. The high limit of the losses, being at high speed and 20 deg. cent. (68 deg. fahr.), is closely similar; the low-limit lines spread considerably for the higher loads. The wide difference between Axles *B* and *H* is also noticed at once.

The loss and the efficiency curves of any one axle, as shaped by various influences, cross to such an extent that it becomes more convenient to use for a comparison the means of the losses and the efficiencies combined for individual or for several temperature and speed conditions. Such a combination is given in Fig. 32; the curves include all five speeds from 15.0 to 2.5 m.p.h. One set

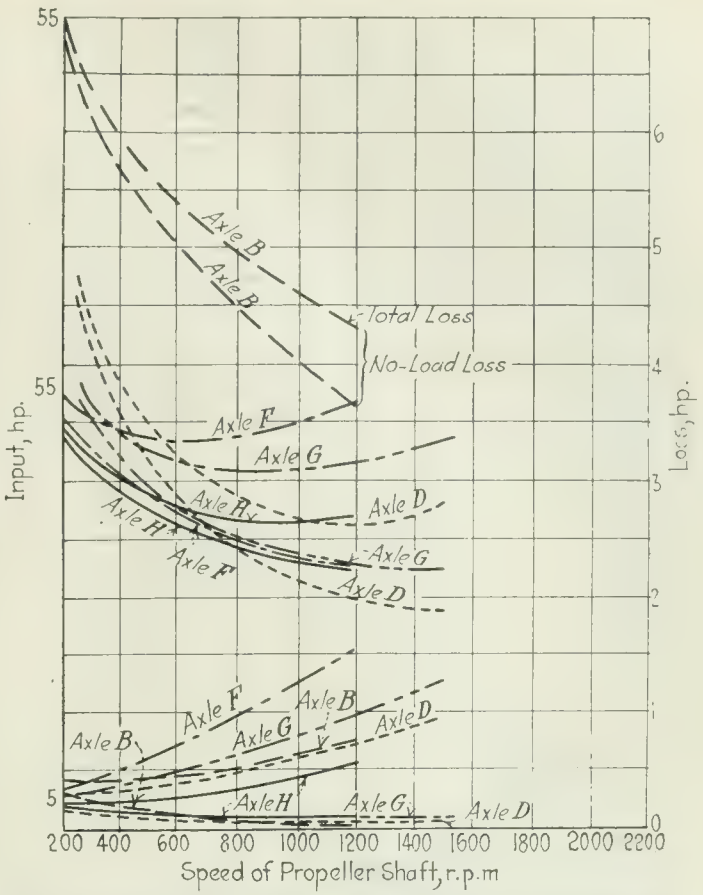


FIG. 27—CURVES OF THE TOTAL AND NO-LOAD LOSSES PLOTTED AGAINST THE PROPELLER-SHAFT SPEED AT AN OIL TEMPERATURE OF 100 DEG. CENT. (212 DEG. FAHR.)

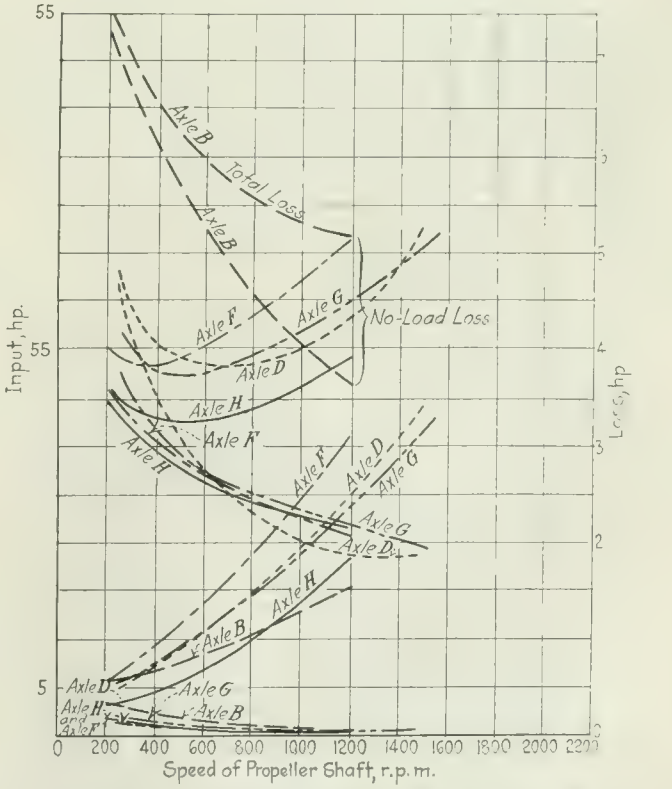


FIG. 28—RELATION BETWEEN THE TOTAL AND NO-LOAD LOSSES AND THE INFLUENCE OF THE SPEED UPON THESE LOSSES AT AN OIL TEMPERATURE OF 20 DEG. CENT. (68 DEG. FAHR.)

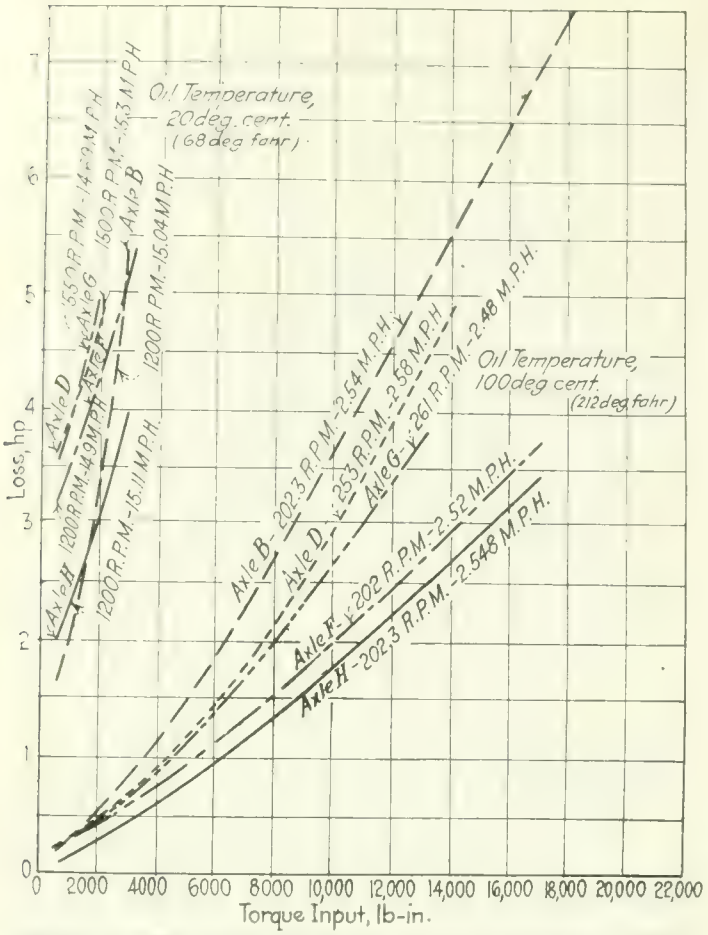
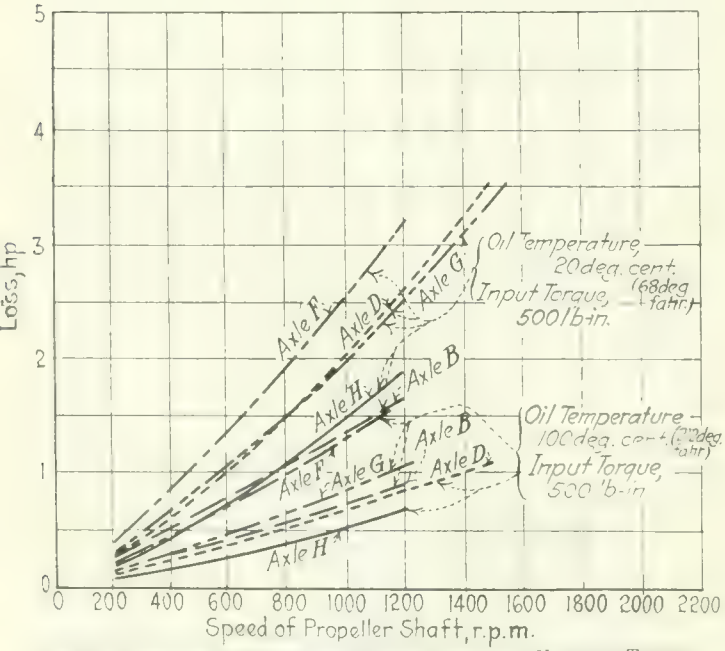

Oil Temperature, 20deg. cent. (68deg fahr.)
Oil Temperature, 100deg cent. (212deg fahr)
Axle B - 202.3 R.P.M. - 2.54 M.P.H.
Axle D - 253 R.P.M. - 3.18 M.P.H.
Axle G - 261 R.P.M. - 2.48 M.P.H.
Axle F - 202 R.P.M. - 2.52 M.P.H.
Axle H - 202.3 R.P.M. - 2.548 M.P.H.
Axle H - 1200 R.P.M. - 14.9 M.P.H.
Axle D - 1200 R.P.M. - 14.9 M.P.H.
Axle G - 1500 R.P.M. - 15.3 M.P.H.
Axle B - 1200 R.P.M. - 15.04 M.P.H.
Axle F - 1200 R.P.M. - 15.11 M.P.H.
Loss, hp
Torque Input, lb-in.

FIG. 29—LOSSES OF THE FIVE AXLES PLOTTED AGAINST THE TORQUE INPUT AT DIFFERENT SPEEDS AND TWO OIL TEMPERATURES

shows the means for the four temperatures, 20, 40, 70 and 100 deg. cent. (68, 104, 158 and 212 deg. fahr.); the other set includes only the last three temperatures.

Table 1 shows the data obtained during the temperature-rise runs for all of the axles. The losses and the temperature-rises for five axles are plotted in Fig. 33.



RELATION BETWEEN THE POWER LOSSES AT VARYING TORQUE INPUTS AND OIL TEMPERATURES AND THE SPEED

The temperature-rises at the time when equilibrium is reached range fairly well with the losses. It will be noted that in Axle *A* the temperature-rise at the rear bearing is closely similar to that in the sump under these operating conditions. In Axle *B*, however, the rise at the bearing is somewhat less than in the sump. This will be referred to in connection with the endurance run. During this test with Axle *C* a number of stoppages occurred, caused by interruptions in the electric power-supply; but, as these did not affect the result materially, the test was continued.

TABLE 1—TEMPERATURE-RISE RUN AT 15 M.P.H.

Axle	Input Hp.	Input Torque, Lb-In	Time Hr.	Time Min		Temperature Equilibrium: Oil Deg. Cent	Oil Deg. Fahr.	Room Deg. Cent.	Room Deg. Fahr.	Rise Deg. Cent.	Rise Deg. Fahr.
A	49.5	2,608	2	20	Sump	108.0	226.4	21.5	70.7	87	156.6
					Bearing	107.5	225.5	21.5	70.7	84	151.2
B	50.0	2,620	3	30	Sump	101.0	213.8	21.5	70.7	82	147.6
					Bearing	86.0	186.8	21.5	70.7	68	122.4
C	50.5	2,646	3	30	Sump	96.0	104.8	23.0	73.4	82	147.6
					Bearing	91.0	195.8	23.0	73.4	78	140.4
D	50.5	2,160	4	00		84.0	183.2	26.0	78.8	56	100.8
F	51.0	2,660	4	20		88.0	190.4	23.0	73.4	72	129.6
G	50.0	2,030	4	15		93.0	199.4	21.5	70.7	80	144.0
H	50.5	2,625	4	20		80.0	176.0	24.0	75.2	58	104.4

The results of the endurance run are shown in Table 2 and the losses and the temperature-rises for five axles are plotted in Fig. 34. A remarkably rapid rise in the

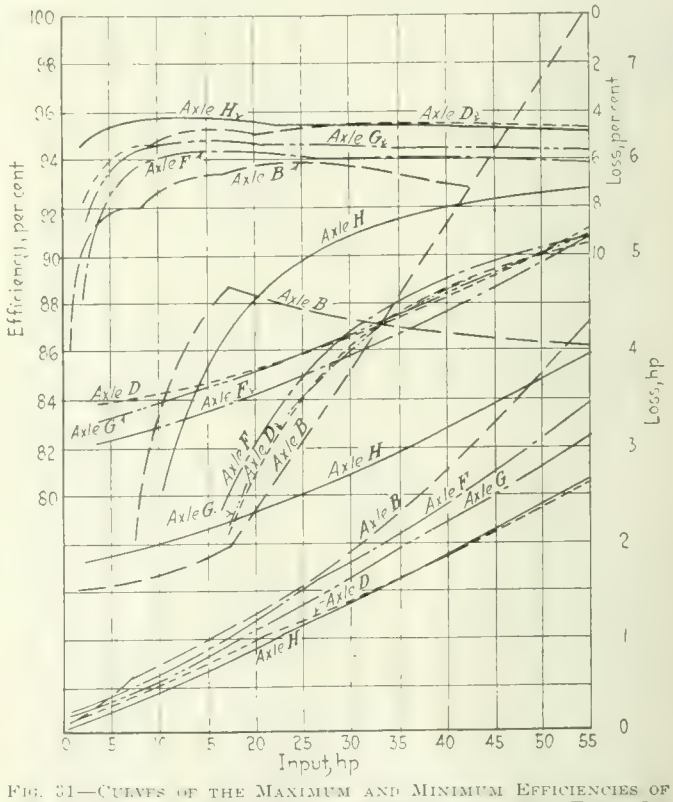


FIG. 31—CURVES OF THE MAXIMUM AND MINIMUM EFFICIENCIES OF THE FIVE AXLES AT FIVE DIFFERENT SPEEDS AND FOUR OIL TEMPERATURES

oil temperature in the Class-B axles *A*, *B* and *C* will be noted. In axle *A*, this applies particularly to the rise observed at the rear bearing, which is lubricated by the oil coming from the worm. In Axles *B* and *C*, the temperature-rise at the bearing is considerably less than in the sump. The explanation of this lies in the course taken

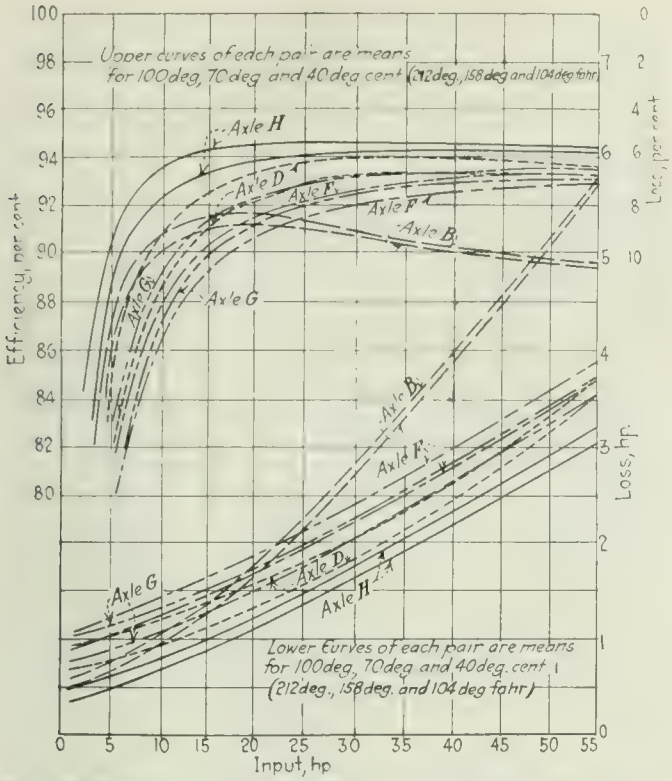


FIG. 32—SUMMARY OF THE MEAN LOSSES AND EFFICIENCIES OF THE FIVE AXLES FOR FIVE DIFFERENT SPEEDS AND FOUR OIL TEMPERATURES

by the oil after leaving the worm, where it is heated; most of the oil from the worm returns directly into the sump, causing a more rapid temperature-rise at this point. The greater length occupied by the bearings, and the greater heat-dissipating capacity of the larger housing-end, further account for the lower temperature observed at this point during this run and the temperature-rise run.

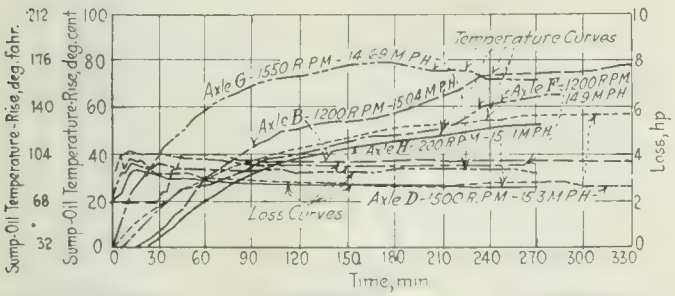


FIG. 33—CURVES OF THE HORSEPOWER LOSSES AND THE TEMPERATURE RISES FOR THE FIVE AXLES WITH AN INPUT OF APPROXIMATELY 50 HP. AT THE HIGHEST SPEED

In Axles *D*, *E*, *F* and *G*, the distribution of the losses as between the central housing and the two wheels would be expected to result in a smaller temperature-rise compared with axles in which practically all the loss is concentrated in the central housing. A lower rise of the sump temperature for a similar loss can be expected in those axles in which a part of the loss takes place in the wheels. The variations in the operating conditions during the endurance runs with several of the axles are explained in the Appendix.

POSSIBILITIES OF IMPROVEMENT

It is evident that the use of a lubricant with a lower viscosity at low temperatures would tend to improve the efficiency of Axles *D*, *F* and *G*, under the more unfavorable conditions of temperature and speed. Such a lubricant would also be of aid in Axle *H*, though there is less room for such improvement in that case. With a knowledge of the viscosity of such a lubricant as compared with that used here, the means of the losses shown in Fig. 32 will be of assistance in estimating the improvement that might be expected in such a case, with any of the axles tested. Of course, it is understood that any such lubricant would have to be no less efficient at the higher temperatures and the heavier pressures occurring at the larger input-torque values. Another feature that

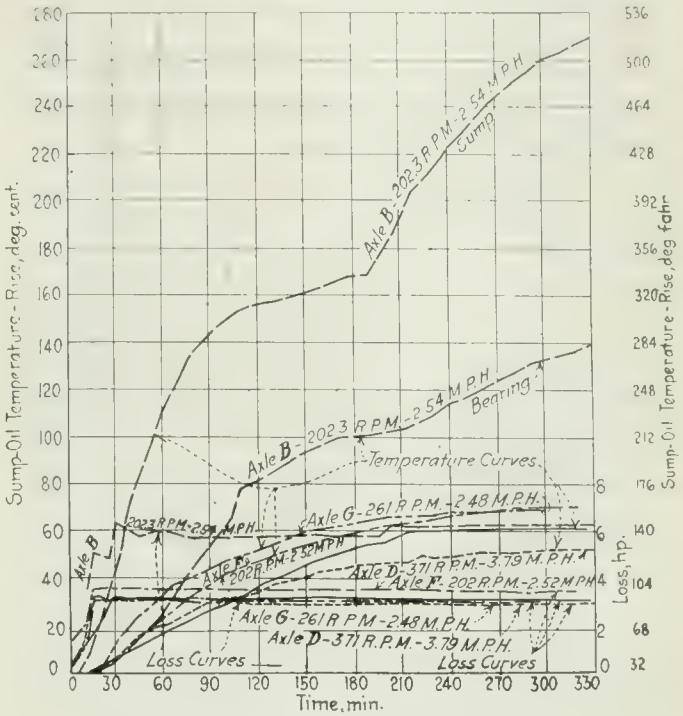


FIG. 34—RESULTS OF THE ENDURANCE RUN AT LOW SPEED AND AN INPUT OF APPROXIMATELY 50 HP.

TABLE 2—ENDURANCE RUN AT 2.5 M.P.H.[a]

Axle	Input Hp.	Input Torque, Lb-In.	Time Hr.	Time Min.		Temperature Oil Deg. Cent.	Temperature Oil Deg. Fahr.	Temperature Room Deg. Cent.	Temperature Room Deg. Fahr.	Temperature Rise Deg. Cent.	Temperature Rise Deg. Fahr.	Total Time, Full Load Hr.	Total Time, Full Load Min
A	48.0	15,000	1	40	Sump	140	284	20	68.0	124	223.2	1	40
	48 0	15,000	4	00	Bearing	385	725	20	68 0	369	664.2		
B	50 0	15,600	1	20									
	50.0	15,600	5	00	Sump	293	559.4	23	73.4	287	516.6	13	10
	50 0	15,600	3	00	Bearing	162	323.6	23	73.4	140	252.0		
	50 0	15,600	4	20									
C	50 0	15,600	5	15	Sump	303	577.4	24	75.2	281	505.8	12	40
					Bearing	186	366.8	24	75.2	164	295.2		
	50 0	15,600	3	5									
D	50 0	8,500	5	10		84	183.2	28	82.4	78	140.4	9	55
	50 0	8,500	4	45									
	47 0	10,700	5	5		110	230.0	30	86.0	82	147.6		
	47 5	10,800	5	5									
E	51 0	11,600	4	20								21	10
	51 0	11,600	4	10									
	55 0	12,400	2	30									
	49 5	15,500	5	00		89	192.2	20	68.0	73	131.4		
F	49 5	15,500	5	00								13	50
	52 0	16,200	3	50									
G	44 5	10,750	4	30		93	199.4	24	75.2	75	135 0	8	30
	47 0	11,400	4	00									
	49 0	15,300	5	00		87	188.6	25	77.0	64	115 2		
	49 0	15,300	5	00									
H	51 5	16,000	5	00								23	30
	51 5	16,000	2	10									
	51.5	16,000	6	20									

[a] For Axle *D*, the speed was 3.79 m.p.h.

suggests itself as capable of improvement is the means used for circulating the lubricant; the present method appears at the higher speeds and viscosity to be an exceedingly unsatisfactory one from the viewpoint of efficiency. It seems somewhat doubtful whether it is desirable to direct a large volume of the oil from the worm to the bearings. The latter might be provided for better by a smaller quantity of oil of lower temperature delivered directly from the sump. A generous-sized central-housing, assuring an ample supply of lubricant without necessitating deep immersion of revolving parts, would be an advantage.

Some improvement no doubt can be made in the worm-type axle by greater accuracy and, possibly, by a modification of the materials and the design. The inherent character of the worm gear may even then stand in the way of sufficient improvement to meet, at least within the limitations dictated by the requirements of Army service, the lower load-losses shown by the gear-drive axles in these tests. It is also a question whether, in actual service, the attention that seems essential for the most efficient operation of a heavy-duty worm-drive, can be had. While the losses resulting from a high-viscosity lubricant are, as found here, not as objectionable as in several of the other axles, the worm drive requires more than the gear drive a lubricant that is able to stand-up under the very highest pressures; for the wear and the scoring of the worm gears in the endurance runs leaves no doubt that the oil-film breaks-down under these conditions.

In using the results described in this paper, it must be remembered that this investigation covered only a limited field and only heavy-duty truck-axles of 5-ton capacity. The general lessons learned are, nevertheless, capable of application in a wider field. The axles tested were of types that had proved useful for commercial trucks, although not all such types were represented. Within each type, the axles tested were of designs that had proved or recommended themselves sufficiently to justify their commercial production by manufacturers of prominence and experience. The worm-type axle was the joint product of the most experienced designers and manufacturers in the field, and it was designed especially for the severe conditions of Army service; this, however, limited the worm gear to proportions that were not the best for most efficient operation. On the other hand, the axles tested do not each represent, necessarily, the most efficient that can be produced of each type; nor do the results obtained permit the conclusion that, in axles of different capacity although apparently similar design, the same relations of efficiency necessarily will prevail. Mechanical efficiency finally is but one of several features, a compromise among which is necessary for every axle. It is, however, a very important feature.

It is hoped that the results of this investigation will, in addition to forwarding the development of efficient axles for Army use, prove of value to the automotive industry generally. These are the two objects that animated the Motor Transport Division in requesting the Bureau of Standards to undertake this work.

Summary

The investigation covered a number of heavy-duty truck-axles representing the several types in successful use. In analyzing the results of the tests it was found possible to separate the losses into no-load losses and load losses, the total loss being the sum of these two. In general, the no-load losses were controlled primarily by the viscosity and the method of application of the lubricant. They were greater in those axles in which the parts rotating at high speeds were immersed most completely in the lubricant. Where a separate body of lubricant was used in the wheels, the losses were increased still further. In a given axle, these losses also increased with an increase in the viscosity of the lubricant, and with the propeller-shaft speeds. The load losses, expressed as torque, were practically independent of the speed and of the viscosity and the method of application of the lubricant. They increased, however, with an increase of the torque input and at an increasing rate. In the case of the several Class-B worm-type axles tested, the increase in the load losses with an increased torque-input was greater than with any of the gear-type axles.

The use of a lubricant of a lower viscosity at low temperatures would improve the mechanical efficiency under the more unfavorable conditions of speed and temperature and would seem advisable. Such a lubricant should, however, be no less efficient than that used in the tests at the higher temperatures and the heavy pressures resulting from the high torque-values. Improvement in the method for circulating the lubricant is suggested as desirable by the results, as the high no-load losses of some of these axles show the present method of circulation to be very inefficient. The characteristic difference between the worm-drive and the gear-drive types is demonstrated by the greater load-losses of the former type.

Appendix

This appendix serves as a record of such mechanical particulars of the axles as are of interest in connection with this paper, of deviations that occurred from the regular test program and of other features of interest in a study of the results. The reasons that led to the selection of Axle *B* to represent the worm type in the summary are explained also.

Class-B Army Axles

In general, the axle and the additional worm and differential-carrier assemblies furnished the Bureau were new parts taken from the Motor Transport Division stock at its Camp Holabird, Md., depot and can be fairly taken as representative material. Sectional views of this axle are shown in Fig. 1, while Fig. 2 shows the worm assemblies as used with ball bearings in Axles *B* and *C*, respectively. The specifications for the worm and gears are, in the main, as stated in Table 3. The same housing, wheels and wheel bearings were used for all the Class-B axles tested.

TABLE 3—SPECIFICATIONS FOR THE WORM AND GEARS

Worm:	
Number of Threads, Right-Hand	4
Linear Pitch, in.	1.1562
Pitch Diameter, in.	3.2650
Lead, in.	4.6250
Lead Angle, deg., min.	24 16
Pressure Angle, deg.	30
Material	S.A.E. No. 3120 Steel
Depth of Carbonization, in.	$\frac{3}{64}$
Hardness of Worm Threads, Scleroscope	70 to 85
Hardness of Remainder, Scleroscope	40 to 50
Worm Gear:	
Number of Teeth	38
Pitch Diameter, in.	13.985
Throat Diameter, in.	14.655
Material	Best Grade of Gear Bronze, Chilled Castings
Copper, per cent	89
Tin, per cent	11
Tensile-Strength, lb. per sq. in.	35,000 to 40,000
Brinell Hardness	70 to 95

The Motor Transport Division had available a considerable supply of worm housings, equipped with ball bearings, considered an alternative standard, shown in the upper portion of Fig. 2, and requested the testing of an axle thus equipped, Axle *B*, to secure, if possible, a comparison with the same type of axle with tapered-roller bearings that has constituted the primary standard design, Axle *A*. In view of the increasing use of annular ball bearings in place of ball-thrust washers and their lower cost and the smaller number of parts, one axle thus equipped, Axle *C*, shown in the lower portion of Fig. 2, was also included among those tested.

Axle *A*

This standard Class-B Army-truck axle was equipped throughout with tapered-roller bearings. A thermocouple for observing the temperature of the sump oil was inserted through the drain-plug. A second thermocouple projected through a hole drilled in the rear-end cover-plate of the worm housing into the space behind the rear bearing so as to register the temperature of the oil where it leaves the cored duct, carrying it from a trough next to the worm to the rear bearing. This bearing, in addition to supporting the radial load on this end of the worm shaft, takes the whole worm-thrust in forward operation. As this axle was the first one tested, the test program differed from that described earlier in several respects. The efficiency tests were made only at 40 and 80 deg. cent. (104 and 176 deg. fahr.), and no tests were made at 12.5 or 1.7 m.p.h. The check-runs were made at 80 deg. cent. (176 deg. fahr.) and the losses at no-load were not ascertained.

Axle *B*

This Class-B Army-truck axle was equipped with single-row annular ball-bearings for the radial support of the worm; the thrust was taken by double ball-thrust washers, mounted as shown in the upper portion of Fig. 2. The differential was carried in tapered-roller bearings of a type differing from those in Axle *A*. One thermocouple was inserted through the drain-plug into the sump, while a second thermocouple projected through the rear-end cover-plate of the worm housing, as indicated in Fig. 8, and was located ½ in. behind the rear ball-thrust washer. The latter bearing takes the thrust-load in forward operation. The test program differed from the one described in the following details: No test was made at 12.5 m.p.h., but the efficiency tests at 8.5 and at 4.6 m.p.h. were made at all three temperatures. The check-run was made only at 15.0 m.p.h. and at 100 deg. cent. (212 deg. fahr.).

Axle *C*

In this otherwise standard Class-B Army-truck axle, the worm was supported by three single-row annular ball-bearings of the same type and size used in Axle *B* for the radial load. These bearings are mounted in the manner shown in the lower portion of Fig. 2; the fits and the clearances of the rear bearings provide that one of these can take only the radial load and the other only the thrust. The use of the standard housing necessitated the addition of the bushings and spacers shown. The differential was carried in tapered-roller bearings of the same type as used in Axle *A*. The location of the thermocouples was similar to that in Axle *B*, one thermocouple being inserted through the drain-plug and the other at the rear of and about ½ in. from the thrust bearing. The test program differed from the one described in the following details. Efficiency tests at 8.5 m.p.h. were made at all three test-temperatures, but no tests were made at 12.5 m.p.h.

Axle *D*

Axle *D*, shown in Figs. 3 and 4, is of three-stage "double-reduction" gear-drive type. The central housing contains the bevel-gear reduction and the differential, the bevel gears having respectively 16 and 40 teeth of 4 pitch and the differential. The axle shafts passing centrally through the load-bearing axle-housing each carry at the wheel-end a 12-tooth spur-gear pinion that, through one intermediate drive-pinion with 22 teeth engaging with a 56-tooth internal-gear ring in each wheel, transmits the power to the wheel. All wheel gears are 3½ pitch. The axle ratio is 11 2/3 to 1, and the axle is regularly employed in a well-known 5-ton truck equipped with an engine giving a maximum torque of about 2180 lb-in. with the low-gear transmission-ratio employed, 4.1 to 1. This results in a maximum input-torque at the axle of not exceeding 8500 lb-in.

When considering the test results and certain deviations from the standard test-program, it must be kept in mind that the manufacturer in making this axle available for tests did not represent it as meeting the requirements of the Class-B Army-truck as covered by the specification given in Table 3.

The bearing equipment of this axle consists of single-row annular ball-bearings, with the exception of a ball-thrust washer for the bevel-gear thrust and one spiral-roller bearing in each of the intermediate-drive pinions where the space is very limited. Two thermocouples were inserted into the differential housing, one entering through the sump drain-plug; the second thermocouple, used as a check, entered through the oil filler-plug at the rear and extended into the body of the housing.

The test program differed from the one described in the following details. No test was made at 12.5 m.p.h. The endurance run with input of 50 hp. was made at a speed of 3.8 m.p.h., corresponding to 8500 lb-in. of torque, thus representing respectively the maximum power and torque conditions that can be imposed by the engine and the low gear-ratio with which it is used. This results, if the losses are ignored, in a torque of just under 100,000, lb-in. at the wheels. As the axle had not been tested previously at this speed, an efficiency test at 3.8 m.p.h. was made for checking purposes, just preceding the endurance run. During the progress of the endurance run, the Motor Transport Division requested that efficiency tests also be made with this axle equipped with a different bevel pinion and gear for a total axle-ratio of 13 1/3 to 1. The endurance test was therefore discontinued after two 5-hr. periods at full load to prevent a possible failure or more severe wear of the other parts for which no spares were available.

Axle *E*

This is a similar axle to Axle *D*, but fitted with a new bevel pinion and gear of respectively 14 and 40 teeth of pitch 4 for a total axle-reduction of 13 1/3 to 1, together with new pinion-shaft bearings. All else was left as before. The particulars given under Axle *D* in regard to the maximum input-power for which this axle is used by its manufacturer apply here as well.

In view of the tests made with Axle *D*, the schedule for the present axle was limited to a 3-hr. run at 8.1 m.p.h. with up to 23-hp. input, followed by a 2-hr. run at 2.5 m.p.h. with a similarly increasing power-input. Then followed efficiency tests at 15 m.p.h. with the oil temperature at 40, 70 and 100 deg. cent. (104, 158 and 212

TABLE 4—AVAILABLE DATA COMPARED WITH THE RESULTS FOR AXLE *D*; SIMILAR SPEED AT THE PROPELLER-SHAFT

Propeller-Shaft Speed, r.p.m.	High, 1,500		Low [illegible]	
Axle Ratio	13 1/3 to 1	11 to 1	13 1/3 to 1	11 to 1
Speed, m.p.h.	13.4	15.3	[illegible]	2.58
Power Loss, HP				
Input, hp.	[illegible]	1.98	2.06	[illegible]	[illegible]
	[illegible]	2.64	2.62	1.95	2.05
	500	3.44	3.51	4.02	4.20
Input Torque, lb-in.	500	2.03	2.08		
	1,000	2.45	2.43		
	2,000	3.33	3.38		
Input Torque, lb-in.	[illegible]			[illegible]	[illegible]
	6,000			1.47	1.55
	12,000			3.80	[illegible]

deg fahr.) and at 2.5 m.p.h. at 40 and 100 deg. cent. (104 and 212 deg. fahr.). The endurance test then completed the series.

For the endurance run, the operating speed corresponded to 2.48 m.p.h. and the first two 5-hr. periods were made with a power input of 47.5 hp., corresponding to 10,700 lb-in. of torque. Taking into account the axle ratio of 13 1/3 to 1 and ignoring the losses, the wheel torque figures 143,000 lb-in. as compared with 100,000 lb-in. for Axle *D*.

The limited efficiency-tests permit a comparison of the influence resulting from the change in the gear-ratio. The available data can be compared with the results for Axle *D* on the basis of either similar speed at the propeller-shaft or at the wheels. The values stated in Tables 4 and 5 are obtained by reducing the data in both of these ways.

From Table 4, it is seen that, on the basis of propeller-shaft speed in revolutions per minute for either the same horsepower or torque-input, the power losses do not vary much. Assuming the same wheel-speeds as in Table 5, the power losses are higher for the 13 1/3 to 1 axle-ratio for any given input-torque, and increase at a greater rate with an increasing horsepower-input at the low gear-speeds.

Axle *F*

Axle *F*, illustrated in Fig. 5 is another representative of the internal-gear type and manufactured for commercial trucks of 5-ton rating.

The cast housing, containing a bevel pinion and a gear of respectively 19 and 35 teeth of 3½ pitch and the differential, is located in front of the forged dead-axle. The jackshaft pinions of 14 teeth of 4/5 pitch engage with internal-gear rings with 73 teeth. The gear ring departs from the more usual practice by being welded to a spider, the hub of which, in turn, is bolted to the wheel hub. The total reduction ratio is 9.60. The bearing equipment is as follows: The pinion-shaft support consists of one single and one double-row annular ball-bearing; the differential is carried in two double-row ball-bearings. A single-row annular ball-bearing is mounted next to the jackshaft pinion, and each wheel is carried on two double-row ball-bearings. The housing does not extend in the usual manner to the wheels, but stops near the spring-pads where its ends are carried in spherical seated brackets for the purpose of relieving the strains otherwise set up by the distortion of the dead axle. Two torque braces prevent any rotation of the housing. This axle is designed for the use of oil instead of grease in the wheels, the design being modified with this in view. The standard test-lubricant was therefore used in the wheels as recommended by the axle manufacturer. Two thermocouples projected respectively through the sump drain-plug and the oil filler-hole in the rear of the housing. The test program was regular in all respects.

TABLE 5—AVAILABLE DATA COMPARED WITH THE RESULTS FOR AXLE *D*; SIMILAR SPEED AT THE WHEELS

Speed, m.p.h.	High, 15.30		Low [illegible]	
Axle Ratio	13 1/3 to 1	11 to 1	13 1/3 to 1	11 to 1
Propeller-Shaft Speed, r.p.m.	1,720	1,500	289	[illegible]
Power Loss, HP.				
Input, hp.	[illegible]	2.06	2.58	[illegible]
	[illegible]	2.02	2.73	[illegible]
	[illegible]	3.51	5.47	4.16
Input Torque, lb-in.	[illegible]	[illegible]		
	1,000	2.43		
	[illegible]	[illegible]		
Input Torque, lb-in.	[illegible]		[illegible]	[illegible]
	[illegible]		1.76	[illegible]
	12,000		4.27	[illegible]

Axle *G*

Axle *G* is an internal-gear type in regular production and is in use in commercial 5-ton trucks, as is shown in Fig. 6. The cast housing carrying the bevel pinion and a gear of respectively 16 and 39 teeth of 4 pitch is located in front of the forged dead-axle. The jackshaft pinions of 13 teeth, 4 pitch, engage with the internal-gear rings with 67 teeth. The total axle-ratio is 12.56 to 1. The manufacturer was unable to furnish the necessary parts for an axle ratio different from this.

The bearing equipment is as follows: The pinion shaft is carried on one spiral-roller bearing and one double-row annular ball-bearing; the differential is carried by two spiral-roller bearings each backed by a ball thrust-washer; the pinion end of the jackshaft has a spiral-roller bearing; the wheels are each mounted on one cylindrical solid-roller and one double-row annular ball-bearing. Two thermocouples were inserted into the differential housing, one entering the sump through the drain-plug; the other, used as a check, was inserted through a pipe-plug in an inspection-hole in the front of the central housing. As this axle is designed for the use of grease for lubricating the internal gears, a heavy graphite grease, Dixon No. 680, was used in line with the recommendation of the axle manufacturer.

The test program was the standard one except for a modification of the load in the endurance run on account of the different axle-ratio. Although guaranteed for a maximum torque-input of 20,000 lb-in. with the ratio of 12.56 to 1, this ratio, higher than the range of interest to the Army, might be lowered readily by the substitution of a different bevel pinion and gear. The axles with ratios within the desired range were loaded during the endurance run with about 90 per cent of the specified maximum torque-input of 17,000 lb-in. The manufacturer of this axle furthermore listed an optional ratio of 10 to 1, though he had not found any call for it. It was found that, if the test axle with a ratio of 12.56 to 1 were subjected to about 11,000 lb-in. of input torque, the gears would on the average be loaded to closely the same average amount as would be the case with 90 per cent of 17,000 lb-in. of torque applied to this axle if equipped with a ratio of 10 to 1; the bevel pinion would then carry about 5 per cent overload and all other gears would be underloaded about 12 per cent. The

wheel torque would be about 5 per cent less than that of the axles with 9.5 ratios during the similar tests.

Axle *H*

Axle *H*, a triple-reduction type with all gears located in the central housing, differs considerably in design from the more conventional types as seen from the sectional views in Figs. 7, 8 and 9. In single-reduction-type axles with bevel or worm drive, it is the general practice to locate the differential on the axle shafts, although, in a few cases, it has been placed on the primary shaft. In the internal-gear and in some double-reduction axles having all gears in the central housing, the differential is on the secondary shaft. One of the principal features of Axle *H* lies in the location of the differential on the primary shaft.

Two spur-gear reductions 13 to 23 teeth, 4/5 pitch, to the first intermediate shafts are followed by bevel drives of 18 to 36 teeth of the same pitch between these and the second intermediate shafts and the final spur-gear drives with 12 and 32 teeth, 3/4 pitch, to the axle shafts. The total axle-ratio is 9.44 to 1.

The bearings throughout were annular ball-bearings of the single and double-row types, the latter being used where thrust loads occur. Two thermocouples were used in the central housing, one projected through the drain-plug and the other, used as a check, was inserted through one of the cover bolts in the right front corner of the housing and reached about half-way down. The test program differed but slightly from that already described. In view of the slight change in the losses with the oil temperature at the lower speeds, the tests at 4.5 and 2.5 m.p.h. were made at 40 and at 100 deg. cent. (104 and 212 deg. fahr.).

Explanatory Notes

It is desired to record and explain a few departures from the observed values of the losses in the plots

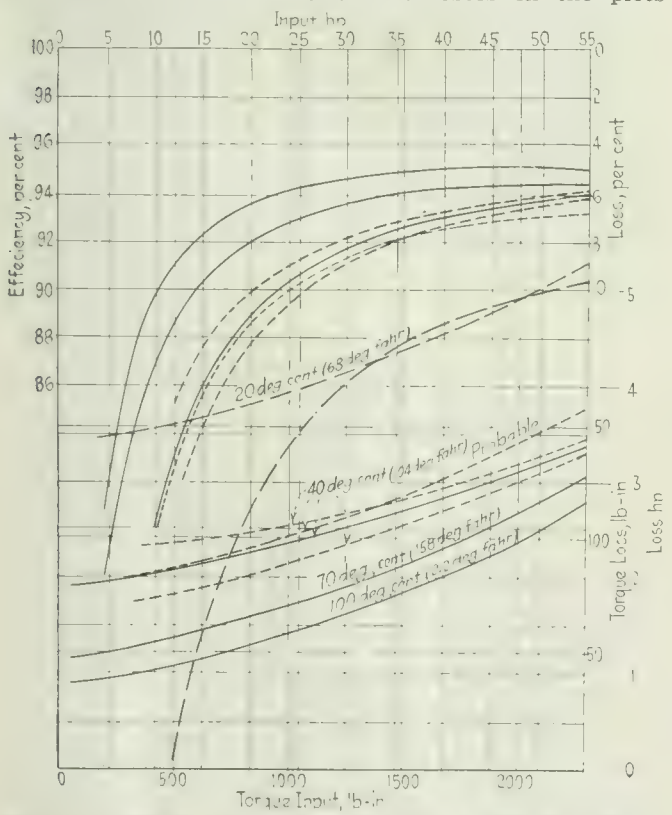

Input, hp
Efficiency, per cent
Loss, per cent
Torque Loss, lb-in
Loss, hp
Torque Input, lb-in
20 deg cent (68 deg fahr)
40 deg cent (104 deg fahr) Probable
70 deg cent (158 deg fahr)
100 deg cent (212 deg fahr)

Fig. 35—Curves of the Losses in Axle *D* at a Speed of 15 M.P.H. and an Oil Temperature of 40 Deg. Cent. (104 Deg. Fahr.)

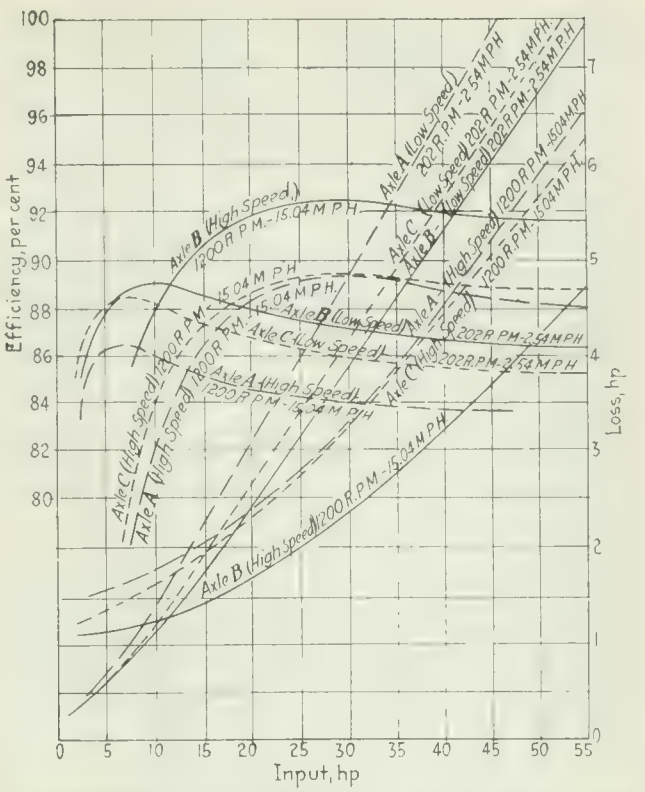

Efficiency, per cent
Loss, hp
Input, hp
Axle B (High Speed) 1200 R.P.M.-15.04 M.P.H.
Axle A (Low Speed) 202 R.P.M.-2.54 M.P.H.
Axle C (Low Speed) 202 R.P.M.-2.54 M.P.H.
Axle B (Low Speed) 202 R.P.M.-2.54 M.P.H.
Axle A (High Speed) 1200 R.P.M.-15.04 M.P.H.
Axle C (High Speed) 1200 R.P.M.-15.04 M.P.H.

Fig. 36—Curves of the Losses and the Efficiencies of Three Worm-Drive Axles at the Highest and Lowest Speeds and an Oil Temperature of 40 Deg. Cent. (104 Deg. Fahr.)

presented. In some cases the spread between losses observed at the different temperatures is larger at the heavy than at the lighter loads. As stated earlier, the tests at each speed were made first at the lowest temperature used. As this was the first occasion that the axle was subjected to the high torque-values applying in the area of the increased spread, it is reasonable to suppose that the losses would decrease more in subsequent applications of the heavy torque, at higher temperatures, than appears justified by the reduction in the no-load losses resulting from the change in the temperature of the lubricant.

A few other cases at high power-input and low speed show a greater loss at 100 deg. cent. (212 deg. fahr.) than at lower temperature. This was at first accepted as resulting from a breakdown of the oil-film, as might be expected at very heavy pressures. Such a breakdown may possibly explain a part of these apparent inconsistencies; however, consideration of a number of these cases and the order in which the tests were made seems to indicate that the explanation given above holds good in these cases also.

A good demonstration of the magnitude of the losses caused by the oil in the wheels is found in a case where a change in these losses during a test seemed to warrant an adjustment.

In Fig. 35, four curves are shown for the losses in Axle *D* at 15 m.p.h. and 40 deg. cent. (104 deg. fahr.) oil temperature. The upper of the two curves drawn with long dashes shows the losses observed while the power input was being increased; the similar lower curve represents the readings with a decreasing load. The wide variation seen is due to a change in the temtemperature of the lubricant in the wheels; when the first observations were taken, this temperature was well below 40 deg. cent. (104 deg. fahr.). As the test pro-

gressed, it was increased by the heat generated by the prony brakes so that, when the loss at high loads was observed and while decreasing the load, it was considerably above the nominal test-temperature of 40 deg. cent. (104 deg. fahr.). As a result the losses in the wheels were markedly reduced. The full-line curve drawn as the mean of the two observed curves is, however, too low for the higher values of power input; therefore, the dotted curve probably represents closely the actual losses with the wheel oil at 40 deg. cent. (104 deg. fahr.). Curves plotted later of the losses in relation to the temperatures confirm the correction as a fair estimate.

Similar changes in the loss, but of smaller magnitude, occurred at lower speed until, in conformity with the small no-load losses at very low speeds, they were not traceable. The other axles with the lubricant in the wheels also showed such changes but to a less extent. The latter is probably due in Axle *F* to the fact that the oil chamber is less closely connected with the wheel casting than in Axle *D*; in Axle *G*, on the other hand, the use of grease instead of oil may account for the less marked changes.

Where the observed values have been departed from, the adjustments made are considered as qualitative rather than quantitative. The original plots, covering individual axles and available to those interested, show both the observed losses and the adjustments made during the course of the tests.

Changes in Axle Condition

The changes occurring in axle condition during the preliminary runs result in some reduction of the losses. In the worm type of axle, it was found that the reduction in loss might be 15 per cent or more for medium and higher loads at 8.5 m.p.h. In the gear drive, the reduction was found to be very much less. The change decreased as the preliminary tests progressed. The first application of a higher torque during the main tests at the lower speeds resulted in an apparent adjustment to this new load-condition and sometimes, also, in a slight further improvement at lighter loads. As a result, in some check-runs made after the efficiency tests at all speeds had been completed, a slightly lower loss than in the main test was observed for the higher speeds; for the lower speeds, the change was in most cases so small that it might be accounted for in other ways and in some instances there was a slight increase in the loss.

Selection of Axle *B*

The reasons for selecting Axle B to represent the worm type in the discussion of results will be clear from the following explanations. In the tests of Axles *A*, *B* and *C*, the variation in the worm-gear losses was so wide that no reliable comparison of the varying bearing-equipment could possibly be obtained. The changes taking place in the worm gears in these tests preclude the use of the same set for different bearing equipment. The variation as between these three axles as seen in Fig. 36 was so great that a number of worms and gears taken from Army stock were measured carefully and records of their operation taken on a Saurer gear-testing machine by the gage section of the Bureau. Two other sets later used in special tests in a Class-B axle were checked similarly. Variations in the measurements were found which, it seems, should be avoided to assure the most efficient worm-drives. Hardness tests were made on five worms used in the tests, as well as on three worm-gears; but these, as well as chemical analyses made of four gear-rings and wear tests made on an Amsler wear-and-friction testing-machine with discs cut from four of the gear rings, seem to indicate that these differences in the hardness, the composition and the wearing quality probably had less influence on the results than the accuracy of workmanship and adjustment. The last-named was made with far more care than could be expected in service, but it is not possible to assure an entirely equal adjustment in the several axles; and, if made without any load, the adjustment will be lost when power is applied and the contact between the worm and the gear will change. From the foregoing, it would seem that little reliance can be placed on any comparative efficiency tests of similar axles equipped with different bearings when subjected to loads of a relative magnitude similar to full-torque operation of these Class-B Army-axles.

The selection of Axle *B*, with its higher efficiency, to represent the worm-drive type, is made with a view to giving the type the benefit of any doubt. The ball bearings, although not used in the majority of these axles in service, are a second standard, and the worm and the gear are fully representative standard stock and possibly even better than the average.

AUTOMOBILE FATALITIES

THE number of automobiles in use in this country has increased five-fold since 1915, but the number of automobile fatalities has but little more than doubled. The education of the motorist and the pedestrian alike, the more stringent regulation of traffic and the institution of safety campaigns have helped to pull down the ratio of automobile fatalities to automobiles in use. Thus the death rate per 10,000 automobiles registered was 24.0 in 1915, 18.2 in 1917, 15.5 in 1918, 12.0 in 1920, 11.9 in 1921 and 11.6 in 1922. Despite these comforting indications the fact remains that automobile fatalities are increasing in actual number at the rate of 1000 a year.

The Interstate Commerce Commission's bulletins show the following automobile highway grade-crossing casualties for the years 1919, 1920 and 1921, based upon the reports made to the Commission by the railroads:

Year	Killed	Injured
1919	1,232	3,558
1920	1,273	3,977
1921	1,262	4,025

The analysis of 501 fatal accidents and 1000 non-fatal accidents that occurred in Massachusetts during 1922 showed the following:

Cause	Fatal	Non-Fatal
Motorist at Fault	347	826
Pedestrian at Fault	121	134
Motorcyclist at Fault	18	24
Others at Fault	35	38

Speed caused 158 of the fatal accidents and 361 of the non-fatal accidents.—National Bureau of Casualty and Surety Underwriters.

Discussion of Papers at the Chicago Service Meeting

THE discussion of the papers presented at the recent Chicago Service Meeting was submitted to the authors and the discussors for revision and further comment and is published herewith. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum amount of effort.

SERVICE AND ITS RELATION TO THE INDUSTRY

BY OTIS C. FUNDERBURK

AFTER outlining the ideas regarding the success of a service-station which the author had when he entered the service industry, such as a convenient location and consistent newspaper advertising, the 24-hr. service that his organization is prepared to furnish for Ford cars is described briefly. The methods employed in getting service work on Lincoln cars by the use of circular and personal letters are commented on briefly, it being pointed out that January and February are now two of the best months in the year as regards the amount of service work performed instead of being dull. The importance of a modern tool-equipment and the careful selection of the personnel for a service-station are mentioned, emphasis being laid upon the fact that in a service organization the men should have a fundamental education for their work.

A number of pieces of special equipment that have been purchased from outside manufacturers or developed by the author's own organization are illustrated and described. Among the latter are an inclined platform for raising the front end of the car when work has to be done on the engine from underneath, a special spark-synchronizing device and a rig for relining brakes. The importance of having a thoroughly competent floor-man to meet the customer and write the repair order is emphasized; and a brief description of the method of handling work in the shop is given together with an outline of the road-test that is made of all jobs that necessitate any change in the running-gear of the engine. The importance of delivering the car to the owner on time, clean and free from tool-marks is pointed out.

The flat-rate system of service charges receives consideration, the author being of the opinion that eventually practically all maintenance work will be handled on that basis. The way in which the flat rates charged by his service-station were arrived at are outlined briefly. An indication of the way in which cost data on an operation are secured and distributed among the various accounts completes the paper. [Printed in the March 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN CLYDE JENNINGS:—Maintenance is the biggest part of the biggest industry in this Country. When gaged by the number of people employed and by the turnover, it is bigger than car building. The figures of 1922 show that about $2,000,000,000 worth of new cars was sold at retail and I believe that further investigation will show that the turnover on the maintenance, parts, labor and the like was about $5,000,000,000. Maintenance has been largely a correlation of the automotive industry, but things are changing rapidly and, instead of being a correlation, I think maintenance will be one of the main supports. It helps to give the dealer in cars a well-rounded business; it gives him something that goes ahead. It is not unusual for a dealer not to sell a car for a week, but anyone who has been in a service-station will agree that a week does not pass without calls for the service department.

Automotive engineers have been a trifle slow in taking this up, for what we might call a selfish reason on their part. If some of them had been looking toward their own financial benefit, they would have seen years ago that the big thing in the industry is service; that it was a growing business and that the designing of cars is not a growing business to the same extent. I have no wish to intimate that the designing of cars has reached a static condition, because I look for great and marked improvements in the details. An engineer is at home when he is considering details, but if he wants details he will get them in the service-station and details are important in the service-station just now. Details always are important until a craft or trade takes a set place. That is why such men as Don T. Hastings are devoting their attention to service; they are developing the details that are necessary for a better understanding of the question, the things that eventually will produce system in the maintenance business.

The question of flat rates is a question of undoubted importance. We do not need flat rates to produce a good job, but they help to get a good job because they drill the poor workman in the way he should go; but we do need them to sell maintenance, and anything that has the turnover that the maintenance business has must have a selling-point. This $2,000,000,000 worth of cars that I spoke of is sold by some 32,000 dealers. You can take your own estimate of the average number of salesmen employed by each dealer and multiply it by 32,000 to get an idea of the total number of automobile salesmen, but how many salesmen are selling the $5,000,000,000 worth of maintenance? People are buying maintenance because they have to, and they are getting the reaction of people who do things because they have to, who go to the few shops where the buying of maintenance is made a pleasant, understandable thing. When a customer comes in he must be greeted properly, he must be sold properly, he must be told that he must leave the car and the salesman must return the car to him in good condition.

After the maintenance work has been done, it must be serviced, and I think that is the difference between main-

tenance and service. When you buy an automobile, you deserve service; you deserve to be greeted properly, to have an attractive place to go to buy that car and all the things that go with merchandising, such as the 90-day guarantee and the readjusting of the valves. Many of those things are service but, after service has been given, then what have you? If you sell a customer a $225 job of maintenance, then you must service that maintenance; if you reground the cylinders and put in new pistons, you owe him the same service on the maintenance job that you gave him on the new car. If a readjustment must be made to make the job a good one, you owe it to him; that is service. But if he has bought the cylinder-regrinding job and you are servicing that, you do not owe him such maintenance as relining the brakes. We need to sell the parts and we need to service them.

C. F. CLARKSON:—The flat-rate system probably will be satisfactory for much the same reason that the tariff on imports is considered satisfactory, if there is definite knowledge as to what it is and will be over a reasonable length of time, and within liberal limits as to figures.

The word "service" is used, of course, to indicate a great number of things. Many of the meanings attributed to it are vague. Its general meaning is very broad; there is scarcely a word of broader import in our language. It suggests matters of an ill-defined character. This is undoubtedly a main reason it has lacked specificness and concreteness in our field.

The saying that the road to greatness is the road of service is about as old as the hills; and it is as true and as enduring as the hills. It is time that we made a more thorough application of the principle. It is obvious that the prestige and the lasting success of automotive companies, particularly those engaged in the passenger-car and the motor-truck fields, depend upon the satisfaction their products render. Service is an integral part of their activities that cannot be long ignored. To maintain a position in the highly reputable and prosperous way that it should be maintained, and will be maintained by those who shall survive through the coming years, motor-vehicle builders and dealers must meet in a fair and square manner their responsibilities, which are inextricably linked with the needs of their car-using customers. They must give to receive. That axiom is pertinent with peculiar force in our industry.

There is a clearly defined indication that our political and social problems cannot be solved by any methods other than those that have been followed in recent general scientific and engineering progress; and that they will be solved by those modern effective methods. Surely, one of the first thorough-going reductions to practise in this respect should be in the servicing of the millions of motor-cars now in operation, not to speak of the many millions more to come. What has been said here today by very well qualified speakers defines pretty plainly just what steps should be taken.

The securing of practical success must be based on an ideal. Frequently, stressing the ideal arouses the thought of impractical notions, but a proper ideal is essential and usually is the governing factor in the success of a business. Having the ideal, the procedure of how it shall be made concrete in practice must be settled. The ideal, or the right idea, which is another name for the same thing, must be physically embodied by action, which alone will show definitely what the ideal really is and, in turn, how that which has previously been set up should be modified according to circumstances. The essential thing is that the vehicle vendors and the others concerned desire to do, and do, what their instinct tells them is the right thing to do; and that it shall be said that what they do is done. The adequate working of their spiritual "self-starters" results in mutual good for the buyer and the seller. The longer the comprehensive solving of the service problem is deferred, the more arduous it will be to accomplish. The statement that we reap what we sow is scientifically correct.

The securing of big results involves conquering great difficulties. The establishing as fully as possible of desirable conditions in the very complex and widely scattered field of automobile service requires long and thorough study by the best brains of the industry. All the phases of the unbeatable law of compensation are latently present. The matter should be carried forward with dispatch, and with all the solemnity of a pledge for the good of the industry and the public. The typical respective responsibilities should be clarified and met, not blinking that prime element, human nature. We should be as little lacking as possible in knowledge of the vital features of satisfactory service. The time to take intelligent action is in advance of the coming of obstacles that may be nearly insurmountable. Let us do the best work of which we are capable on the great service problems that are before us.

DON T. HASTINGS:—With regard to special equipment, we have done very much as Mr. Funderburk has done. The tool I described for expanding the tubes to take out the rattle in the steering-gear cost us $15 to $20 at first; now it costs about $2.50. Another tool is a piston-position indicator; it works in through the spark-plug hole and it is not necessary to take off the head to determine where the piston is. It is a lever-multiplying device that is of great assistance in setting the timing. We have a front-wheel lining-device different from the one that has been described; to my mind, it is somewhat simpler to use. It is a bar having two levers, one mounted on each end. The levers fit against the felloe of the wheel and each carries a pointer that registers on a graduated bar; in about 15 sec., one can determine whether the wheels are properly lined-up.

CHAIRMAN JENNINGS:—How many think in the terms of the man who does most of the work, not those of the man who runs the shop, who can afford to have an engineer at the head of it, but the man who must be content with a mechanic, and with certain limitations in interpreting these ideas to his own organization? It is always well to apply ideas to a small organization. Whenever we describe a high-class shop that has all this equipment, we try to tell later what it means to the little fellow; it means very much to him. Consider how many cars are serviced by small stations. One-third of the cars are on the farm; naturally, they cannot go to Mr. Funderburk's station, so they go to a nearby station.

J. W. LORD:—In connection with the expansion tool Mr. Hastings described, it was developed in a service-station, was taken up by the factory and then was made for about one-tenth the cost of the first one. I think that the development of a tool in a service-station, it being taken up by the factory and then sent out, is something that the factories should note and consider very seriously; that much better action will result than if the factory should try to develop it.

CHAIRMAN JENNINGS:—In other words, the man in the service-station gets the actual contact with the vehicle as it is.

MR. LORD:—I think the factory service-department broadcasts tools that it should not broadcast; it would be better if its representative went into the service field to find out what the various tools are that have been de-

veloped for a particular job, because very often some better tools can be developed.

B. M. IKERT:—In an instance that I know of personally, the cooperation of a manufacturer's equipment is helping greatly in the field of service. Men who work on a certain very popular car are under the impression that the work is fairly accurate on the block; they turn the block upside down, then hook up the burning-in machine. We checked a number of blocks and found a difference of 1/16 in.; and that makes a big difference. One company has brought out a burning-in machine with which it locates from the bottom of the block; the block is put right-side-up and is always properly lined-up. Few mechanics can appreciate a variation in the height of a block. This is a case where the manufacturers have checked-up and are really helping in the field of service.

Mr. Hastings spoke about attaching a postal card to a car and asking the owner whether the work had been satisfactorily done. With the facilities that most men have who do that kind of work, I should expect the customer to take it for granted that I was sure the job was right and did not need to ask his opinion. I may be wrong. I never ran a service-station; but if I had a properly tooled shop, if my men were right and I had an inspector on the job, I should feel entirely confident that the jobs had been done right. Mr. Hastings mentioned a mechanic who left the cotterpins out of the connecting rods. Has he a man who inspects those jobs before they are put together? In one service-station in St. Louis, before a mechanic puts a rear axle or a crankcase together, an inspector looks over every point and passes on it before the man can complete the job.

MR. HASTINGS:—Regarding the cotterpins, the oversight was detected before the car was sent out. The inspector passes on the work before the workmen close up any job.

MR. IKERT:—We draw too sharp a line of demarkation between service and sales; they really are the same thing. The days are past when we could go into a salesroom and then out into a dirty repair-shop through a cubby-hole in the wall. I was in a salesroom recently and was led gradually through to the shop; then I thought we were still in the salesroom. That shows how close sales and service are. We are making too many bones about some service matters; many dealers in this country have fine service-stations and, although they have many problems, they are just everyday problems. Customers want the same kind of service they get in any other line of business. As I see it, selling maintenance is not more complicated than selling anything else; the dealers that I have talked with in this country who are using the flat-rate system of selling maintenance have told me they never would go back to any other system.

MR. HASTINGS:—With regard to asking an owner whether the work is satisfactory, we find that many times the owner is not satisfied for a variety of reasons. Rather than let it prey on his mind and have him go around talking to his friends instead of telling us about it, we try to find out as soon as possible whether there is a sore spot. If we can reach him the next day, we almost always can clear away that impression, but if the matter is allowed to run for a week, it becomes much worse than it was when the thing happened; and, in the course of a month, we become the most horrible example of maintenance station it is possible to conceive. Frequently, it is some little five-cent thing that really would not have amounted to anything if we had been able to reach him while the thing was fresh. We think it is important enough to follow up.

MR. IKERT:—Do you have in your station a man who represents the customer? I know of a St. Louis company that has a man who looks over the car from stem to stern before it goes out. When he passes on the work, the company feels absolutely sure that the car can be turned over to the customer.

MR. HASTINGS:—That is not delegated to one man alone with us. Our chief inspector is one of the absolutely thorough workmen that you do not find very often; he makes an ideal inspector and at the same time has a way that enables him to get along with the men in the shop. The other men who represent the customer are our service salesmen, who are much interested in avoiding "comebacks" because they must bear the brunt of them. So, we have two groups of men who represent the customer.

As to linking sales and service, it is not service exactly, but we have taken a step this year in the sales department that I think will accomplish that result. We have divided our sales organization into eight teams; each team is under a division sales-manager. Everybody in the organization, except Mr. Williams and myself, has enlisted on one of the teams as a part-time salesman. We pay part-time salesmen 5 per cent on sales and the division manager gets 2½ per cent on any sales that may be made by a member of his team. In other words, we are offering 7½ per cent commission to be paid on sales, so that the service organization and the sales department are linked very closely. So far, the plan seems to be working out very happily. The salesmen, the division managers and the general sales-manager all are getting to know the men in the service organization better. I spend all my spare time preaching the gospel of good service and telling the salesmen what we are trying to do. This seems to be one way to get the close cooperation that we must have if we are to succeed.

L. C. VOYLES:—A point that Mr. Ikert mentioned and that Mr. Hastings has answered, is the matter of being too sure. That is the trouble now; we have been sure, but the other fellow has been doubtful; and we all must admit that one of the problems that confronts the automobile industry today is the feeling on the part of the ultimate consumer. He does not feel that we have the good service that we are talking about and are trying to improve and to bring about. He has the idea that all service-stations are more or less "punk," some more punk than others; and that is a matter of fact. You may continue feeling sure and take a cock-sure attitude with him if you wish, but you must do something to make him appreciate that point, to get him to look at it from your viewpoint.

The plan Mr. Hastings is following is an excellent one; it is something that the owner is not accustomed to and, consequently, will talk about. It would help if we could get him to follow the sign that we see in various places, "If we please you, tell others; if we do not please you, tell us." If everybody would follow that rule, all would be well and good; but it is human nature not to follow it. We damn somebody because something was not done to suit us; not one per cent of us ever go back and tell the fellow who could and really would like to correct it. We do not tell him, we tell everybody else, and some one who does not know the actual facts in the case thinks an awful condition exists. It is this condition that we must break down; we must do something extraordinary to break it down. It strikes

me that Mr. Hastings' plan is entirely feasible and one that could be recommended to all the service-stations in the country.

T. C. PLUMRIDGE:—There is another point in asking the customer whether he is satisfied. A customer brings his car in, wants certain work done and it is done, but something else is discovered in the meantime that should be done. The car goes out; the customer may not know of the extra work that should have been done and, after the car begins to run badly again, he brings it in. If the customer had been asked immediately whether he were satisfied with the work, the service-man would have a "comeback" on him and could say that it was not the service work that was wrong.

MAINTENANCE EFFECTS OF AUTOMOTIVE ELECTRICAL-EQUIPMENT STANDARDIZATION

BY A. H. PACKER

THE author outlines past conditions that led to a diversity of design for similar parts, such as tires and rims, as being analagous to the causes of present variations in automatic electrical equipment intended for identical purposes, and gives specific instances in which such variation has resulted in excessive expense and delay.

Constructive suggestions are made for improvement in regard to reducing the number of types of equipment and standardization of the remaining types, more especially with regard to generators, as a means of making possible better service-station efficiency and a reduction of the investment now necessary because of the carrying of an excessive number of parts in stock. Standardization problems are stated and commented upon, and the advantages of a reasonable degree of standardization for electrical equipment are set forth. [Printed in the March, 1923, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN CLYDE JENNINGS:—There has been a disposition to say that electrical service cannot be mentioned with mechanical service, that it has to be departmentized; but the point is that no car is better than the service behind it. We all admit that, but we all do not admit yet that no car is better than the service behind it regardless of where that service is obtained. Another point worth considering is that if you do not include electrical maintenance in the service-station, you will tell Mr. Car Owner to go two blocks to the left and four to the right to an electrical service-station to get the car fixed. What will happen next? Will you tell him to go down another street to get the axle fixed? I believe it has been said that the nearest "own-made" car patronizes 209 parts-makers. Would you have people shopping round for parts-makers to fix a particular part, the drag-link or the axle or the engine or the generator?

J. W. LORD:—I think standardization of electrical equipment is important; but, at the same time, suppose we did get down to five armatures; these have a different relation, to my mind, from the various makes of tire. If a man makes B equipment with a very fine armature and the machine happens to go wrong, so that it is necessary to replace the armature with an A armature, a B name is still on that machine. If I were a B manufacturer I should not care to have an A armature put into that machine because my name would be damaged if that A armature that was not as good as mine went wrong.

From a service standpoint, I think that, so far as possible, electrical service should be given by the distributor of the car. I have had experience in buying a car and taking it back because the electrical equipment would not operate. I was told "We do not take care of that; you will have to take your car down to such-and-such electrical station." I took it there, they spent some time on it, and the next night I was stuck again without lights. That happened three or four times, and it kept me bouncing back and forth between the people who sold the car and the people who were supposed to give the electrical service. Finally, I told the car dealer that he must fix the car or take it back; and he had it fixed. I think this business of being sent down the street to get this or that done is wrong.

CHAIRMAN JENNINGS:—As I understand it, the point about the armatures was that if a dealer had only five he could be sure to have a B armature in stock to replace the B armature and an A armature in stock to replace the A armature; but he has not a chance in the world of having 160 armatures in stock.

A. H. PACKER:—If you have an electrical unit of a certain make, the maker would prefer that you have an armature of the same make, but at present he has nothing to say about it. In the country, they rewind any armature and after it has been rewound, nothing that was in it originally is left except the iron. The winding is the most valuable part of the armature; that is, the way it is put on and the treatment that is given to it at the factory. The process of impregnating really makes a good armature.

T. C. PLUMRIDGE:—There is some trouble in that engineers are always changing the types of armature or the types of electrical equipment that they put in. I have one of these big sets of blueprints of electrical work, and sometimes I get inquiries about certain electrical parts. As many as three different equipments have been put into one car within a year. I think that engineers should standardize the equipment and not make three changes in one year.

H. R. COBLEIGH:—I know "you can lead a horse to water but you cannot make him drink." The Society has been making standards for a long time, but the standards are not used as much as they should be. The Society has the agency to help sell its standards; namely, a simplified practice committee, and the National Automobile Chamber of Commerce has a corresponding committee working closely with it. We have high hopes that we may be able to induce the "horse to drink" through the activities of this joint committee.

Another way of getting the standards adopted is somewhat akin to that which is being tried to solve the "pirate" parts problem, educating the public. I wonder if we cannot sell the public the advantages and create such a demand for standardized equipment that the industry will have to heed it. If the dealers find out that the customer says, "I want the car that has standardized equipment so that I can get an armature anywhere I happen to be," you will find that the dealer will tell

the manufacturer, "We must have this standard equipment because it is difficult to sell cars without it." The manufacturer then will get busy.

I think Mr. Lord and Mr. Packer were talking about two different kinds of A and B armatures. Mr. Packer was referring to five different types of armature for one make, and all makes using the same five types. Mr. Lord talked as if A and B were different makes, as if he had a Westinghouse generator and, when the armature burnedout, he were given a Gray & Davis. The electrical-equipment manufacturer may object to having some other make of armature put in his generator, but the thing we must keep in mind is what we are preaching all the time in connection with our service work, which is that the car-owner is the fellow to be considered. Let us stop worrying about what the manufacturer likes and does not like and ask ourselves what the owner prefers.

B. M. IKERT:—We have assumed that service and maintenance always will be part of the dealer's business. We have said in times past that perhaps a large part of the work will be farmed-out; perhaps, one big central shop will do nothing but grind cylinders. Are we to farm-out the electrical work the same way? In an electrical shop I can see the advantage of standardizing armatures in that so large a stock would not have to be carried. Not long ago I was impressed by the practice of a company that had an electrical service-station. I said, "I am surprised that you do your own electrical work here." They replied, "Inasmuch as we have sold these cars to the owners we feel that we are responsible to them and we intend to have everything we can do done right under this roof; we do our own electrical work, so that when a man comes in we need not say, 'We do not make that generator, you must go down the street to a man who will fix you up on that starter.' We can take care of him here." It seems to me it is largely a matter of whether we intend to have outside shops specializing in this and that or intend to make it a part of the dealer's business.

MR. LORD:—I am in full sympathy with the idea of the dealer's doing his own electrical work so far as possible. It is my experience that, if something goes wrong with the ignition or the lighting or the starting, the chances are that the man will blame the car, irrespective of what the equipment is, and that the average electrical repair-shop will take twice as long as we take to handle the job. I think we can exert more pressure than the average individual owner. Of course, I am located in New York City and my case is different from that in some isolated community. There should not be one rule for both the big city and the small town. I should like to go much further in the matter of electrical repairs than we have gone. I believe we ought to buy the parts direct and get them direct and not be hampered by electric service organizations, because a job can be done twice as quickly without that interference. If you can finish a job in 2 hr. or ½ hr., it is better than taking the generator out, sending it out, getting it repaired, getting it back the next day and starting the customer on his way in 24 hr. An inflexible policy does not permit this today.

CHAIRMAN JENNINGS:—Some time ago I asked about 35 men, "What kind of car have you? What kind of engine is there in it?" and 35 replied that their engine was the same make as that of the car. They were not careless people; they were business men. More than half of them told me that the electrical system was the same make as that of the car. These men are honest and intelligent and are looking to the maker whose name is on the front of the car to take care of it. The fact that they did not know that the electrical systems were different does not alter the case. The cars that will survive are those into which the people behind them have put honesty of purpose and some intelligence; nothing else will avail. They have produced a very complicated piece of machinery and must do their best to keep it in operation.

As a matter of fact, we have not accomplished anything when we have built an automobile; we have not accomplished anything when we have built a highway. But when we have a highway and an automobile, we have two means to an end, the end being transportation. We must get the attitude that we all are dealing in transportation and transportation only, not in automobiles; when we get that attitude with regard to maintenance, we shall advance; the factories that maintain that attitude are the factories that will succeed. We have two definite propositions. Mr. Lord has pointed out one of them in the big centers of population; the second is that of the small station, which must have an all-round mechanic to keep it going.

THE DEVELOPMENT OF A MODERN SERVICE-SYSTEM

BY DON T. HASTINGS

THE author states that the word "service" has been and still is the most abused word in the automobile language and enumerates some of the causes of poor service. Good service is then considered as constituting a sales asset. The new attitude toward service is described and the progress of the building-up of a combined flat-rate and piece-work system is outlined.

The flat-rate and the piece-work features are analyzed, inclusive of the methods applied to each and comments upon the results obtained. Records form an all-important part, and these are kept on special forms that are illustrated; the method of their utilization is given in detail. The duties of the different members of the service personnel are specified, and it is shown how the different factors are made to combine and produce service that satisfies the car-owner. [Printed in the February, 1923, issue of THE JOURNAL.]

THE DISCUSSION

J. F. PAGE:—Will Mr. Hastings tell us how he arrived at the time limits on which he established the piece rates?

DON T. HASTINGS:—It is just a matter of getting the actual time of the various operations through the time-keeping system in the shop. We had difficulty with some of the men, who tried to complicate the task. They would work, say ½ hr. at one operation and 1 hr. on the next, and then would report 1¼ hr. on the first one and 15 min. on the second. There always will be some persons in an organization who are not willing to cooperate, and afraid you will take something away from them. But

it did not take long to find out what men were making the trouble, and conditions either became so unpleasant for them, with a foreman watching them all the time, that they quit, or else we actually asked them to leave the organization, so that we soon obviated that trouble. Then, as the time records began to come in, we put a man to work posting the actual time of each operation. We had a book with a sheet for each operation. On each sheet we listed the date, the repair-order number, the time and the name of the workman so that, after a short time, we were able to go through them and strike an average for each operation and compare the various times with the average. We found some men, for instance, who would report 5 min. for changing a radiator, which obviously was impossible; on the other hand, once in a while they would take 5 hr. to change a radiator, which was just as unreasonable. We had to go through a large amount of detail work in checking these excessively long or short times, eliminating them and finding the reasons. Sometimes it was only a mistake in posting; they would get the wrong operation number, so that much detail work was involved in separating the times that obviously were wrong. The shop foreman and I had pretty fair ideas of the proper time for a given operation. We could guess it within from 25 to 50 per cent, at least. We did not use a stop-watch; we depended on the honesty of the men.

A MEMBER:—How do you establish the rate of pay of the mechanic for an operation?

MR. HASTINGS:—That was based entirely on the average time computed from the time-study. Then we figured that the men ought to make about 25 per cent more in a day than their hourly rate called for. In most cases, the first estimates have been reduced. In a few cases we found we had set the time too low, although, as the men got used to the work, they speeded-up.

A MEMBER:—Did you rate them all equally as mechanics, or have a different rate for helpers?

MR. HASTINGS:—A man who scrapes bearings is paid a certain amount, and a man who greases a car is paid a certain amount. The foreman has to use judgment in assigning the work to the men. He would not put a helper on a bearing-scraping job; on the other hand, generally, he would not ask a man to put on a bumper if he is a bearing-scraper. He must use judgment, but for a given operation there is a standard rate of pay.

A MEMBER:—Then if you do not have suitable work for the mechanics, you pay for the idle hours?

MR. HASTINGS:—That is our loss. We pay them at the straight-time rate. This is a point that we have not taken care of yet. We intend to establish a lower rate for lost time than the straight-time rate, but the psychological conditions have not yet been right for putting that into effect. It has been done in other places and I am sure that it can be done satisfactorily. We find that probably 75 to 80 per cent of the work comes in between 8:30 and 9:30 a. m. A few jobs, of course, stay in the shop over night, but they are relatively few. Most of the jobs are in the 3-hr. class and under, so that probably one-half the men have nothing to do for the first hour. The result is that we are not insistent that the men be there at 8 o'clock, the regular starting time. If there is a particularly crowded condition, the foreman says to the men, "You be here tomorrow morning at eight"; but they drift in about eight-thirty, so it is all right.

L. C. GREENAMYER:—What percentage of lost time do you figure as efficient service?

MR. HASTINGS:—I cannot give the percentage offhand. Our shop payroll is about $4,000 per month at present; the actual lost time last month cost $250. That is as near as I can give the figures.

MR. GREENAMYER:—I have had the same difficulty that you and every service manager have had regarding the delivering of cars to customers in a satisfactory condition. I found that I could not leave it to the mechanics to cover the upholstery. In my plant, a closed car or one having delicate upholstery is sent immediately to the upholstering department and covers are tacked on that cover the upholstery. These are taken care of in one department and are laundered whenever they show signs of being soiled. I have found that this has saved more money than any other thing.

MR. HASTINGS:—We leave it to the shop foreman to see that the upholstery is covered. We have no upholstering department, but we launder the covers as soon as they become soiled; the foreman pays particular attention to see that the covers are put on before the men start working.

MR. GREENAMYER:—Do you have covers made to fit each model?

MR. HASTINGS:—We use ordinary sheeting.

MR. GREENAMYER:—I find that heavy denim gives the best satisfaction.

J. W. LORD:—Do you give additional compensation for work over the amount on which the flat rate is based?

MR. HASTINGS:—No, except in cases where we shift a man from the contract rate to straight time.

MR. LORD:—It should be of interest to the foreman to see that the men make as much as possible.

MR. HASTINGS:—They do that by speeding-up the straigth-time work to get back on the contract operations that pay the higher rate.

H. R. COBLEIGH:—At a meeting of the Automotive Electric Service Association, while flat-rate and piece-work were being discussed, the question was raised of overcoming the difficulty with the men when it becomes necessary to lower a piece-work price previously established. Mr. Hastings has said that if he were starting a service-station today he would install piece-work at once and make the necessary changes afterward. How would he make changes without creating sore-heads among the men?

MR. HASTINGS:—We did have some sore-heads. In fact, about a third of our force quit. We started the piece-work system on the first day of August and, the evening before, we had a caterer bring in a nice supper. We cleaned out the shop, and set tables there for everybody in the service organization and the parts department. We had dinner, passed out cigars and told a few stories; then I told the men just what we intended to do. I painted the picture as reasonably as possible, tried to show them that it was to their advantage to work under this system and told them of other shops where it had been instituted. We did one other thing at the same time that was calculated to help over the rough spots; we put in group insurance throughout the entire organization. The expense is about $1 per month per individual in the organization. There are two classes, the executives who have a certain amount of life insurance to start with, $2,500, I believe, and the men in the shop who start at $1,000; and these amounts increase with the length of service until the limits are doubled.

The men did not say very much after I had finished talking, although I encouraged them to talk; some asked questions, but the meeting practically was over when I finished speaking. Then I left them to talk things over. We had about 36 men at that time. Within the next week about one-third of them either quit or grew so ob-

streperous in reporting inaccurate time that we asked them to leave. After we got rid of the trouble-makers, the remainder, one-half of whom had been with us for more than a year and some who had worked for many years with various distributors in Detroit, helped us and worked with us. They are thoroughly convinced, I think, that we are trying to be absolutely fair to them; and this is a mental condition that must be secured in a shop before a system of this kind can be run successfully. You must have the men pulling with you, and that means you must be absolutely fair; you must go beyond this fair point sometimes in getting the men's cooperation.

MR. COBLEIGH:—That covers the starting of the system; there always is difficulty in installing a system, but after it has been installed, there is still difficulty in correcting mistakes in the rates that have been established.

MR. HASTINGS:—We have not found it so. The men are making about 25 per cent more than under the old rates. When we put through the last changes in rates, it happened that the number of rates raised equaled those that were lowered, and that was emphasized by the foreman. We found that we had gone too far in cutting the price of certain operations. Where we had gone too far, there was only one thing to do, and that was to raise the price again to the point where the men could make a proper amount of money. It is a matter entirely of having the men believe that they are treated fairly.

MR. COBLEIGH:—Do you make the changes in rates effective at once or at a future date?

MR. HASTINGS:—Whenever we see fit. We post a notice on the board, "Beginning this morning, such-and-such rates are changed." We simply have gone ahead and made changes; there has not been any trouble.

EDGAR GARDNER:—Have you ever considered setting up a reserve so that the non-productive labor would participate in the saving?

MR. HASTINGS:—We studied that carefully for about 10 months but discarded it for two reasons; because of its unwieldiness and second, the difficulties in handling what is called the maximum-estimate system, which is based on the condition of cars when they come in for service. One fellow takes as good care of his car as he would of his piano; his car is in fine condition. The time required on that car is the minimum. Another fellow abuses his car, never greases it and never washes it. The tire required for a given operation on the two cars is very different. The maximum-estimate system is based on giving the careful owner the advantage. That is where the trouble occurs; when you tell the other fellow he has not taken care of his car, you antagonize him; he says, "I grease my car every other day and wash it every night," and so on. He is lying; there is no doubt about it, but you cannot tell him that he is without antagonizing him, and then you have more trouble than if you had made it a flat-rate proposition.

We take care of the participation of non-productive labor in a different way. We give bonuses at the end of the year to our non-productive men. It is difficult to arrive at a rational basis for a bonus for the non-productive group; at least, we have not been able to devise anything yet that is rational, so we have arbitrarily given each man a check of whatever size we deemed proper at Christmas.

MR. GARDNER:—Do you believe that the system really enables a man to capitalize his ability?

MR. HASTINGS:—There is no doubt about it, so far as our experience goes. We have had no trouble in getting good mechanics; they are attracted to the shop because of the report of high wages and good working conditions.

MR. GARDNER:—Have you ever considered paying a bonus on a completed job, based on a percentage of the number of hours' work and the rate of pay? If a job came into your shop that involved possibly three or four different kinds of work, such as transmission work, engine work and the like, have you considered paying a bonus on that job as a completed job as compared with the individual operation?

MR. HASTINGS:—No; we talked about it but dismissed it because of too great complication in bookkeeping. A man may be good with a wrench, a screw-driver and a pair of pliers, yet when talking percentage or bonus, he is lost. It is essential that the men understand clearly the basis on which they are paid.

MR. GARDNER:—Have you ever found that when two men are working on a car and one operation overlaps the other a tendency exists for one man to antagonize the other, to get the advantage of having completed his job first?

MR. HASTINGS:—We have had practically no trouble of that kind since we got rid of the few men who were trouble-makers at the start.

MR. GARDNER:—What is the minimum efficiency percentage of your present plan? For instance, you have one man 125-per cent efficient; he earns 25 per cent more than he would earn on straight time.

MR. HASTINGS:—I cannot say, without referring to the figures in the detailed analysis.

MR. GARDNER:—Do you set a maximum?

MR. HASTINGS:—No, that is left to the foreman's judgment. He sizes-up the men; if they do not come up to the standard, he gets rid of them and gets someone else.

MR. GARDNER:—Do you set a maximum amount that a man can earn?

MR. HASTINGS:—No. One man, whom we had to get rid of finally, was the fastest man with tools that I ever have seen or ever expect to see. In one particular job he changed a clutch-release bearing in about 2 hr. This involved pulling out the floor-boards, taking off the transmission, dismounting the clutch, taking out the bearing, putting it back, assembling the clutch to the transmission and putting the transmission and the floor-boards back. The average time on that job is about 6 hr. I probably would take all day to do it, and then would not finish it. But he became careless; he left a couple of cotter-pins out of connecting-rod bolts one day. After a few things like that, and when we found we could not cure him, we had to get rid of him.

T. C. PLUMRIDGE:—How do you regulate the amount of straight time that the men work?

MR. HASTINGS:—That is the duty of the service salesmen. We try, so far as possible, to put everything on contract. There are some wreck jobs on which it is impossible to establish a flat rate, because we cannot determine until we get inside what the job will amount to. We sometimes guess and quote a price, but that price always includes a large margin because of the uncertainty; probably 25 per cent more than the bill would have been on a straight-time basis.

MR. PLUMRIDGE:—When several men are working in a shop, how do you regulate the straight time? You cannot give one man more straight time than another.

MR. HASTINGS:—The foreman takes care of that. He assigns jobs to the men and it is his duty to rotate the straight time and piece-work so that all the men will have equal chances.

MR. PLUMRIDGE:—You have the chance of a foreman's giving the preference to certain men.

MR. HASTINGS:—Yes; but our foreman does not show

any preference. We have done considerable educational work with our men. We establish certain fundamentals and we talk them day in and day out with little sidelights on them on particular occasions that come up, until our whole crew, I think, thoroughly believes in those fundamentals and is trying to live up to them. If we find a man that will not fall into line, we simply get rid of him. We try the educational method first, and if it does not succeed, we get someone else. It is the business of the service manager or the foreman to pick out the men and educate them.

MR. GARDNER:—An owner will pay for the work, regardless of whether it is done in the minimum or in the maximum time. To a certain extent you are taxing the man that keeps his car in good condition and giving the man who does not take care of his car the benefit. You fix the minimum rate that a man should earn and a maximum rate; you arbitrarily adjust the rates so that the men can earn about so much money; you mention 25 per cent. It looks to me as if you have figured that these fellows can earn 25 per cent and that this amount is about what you intend to give them.

MR. HASTINGS:—That is about the way it works out. They can earn about 25 per cent more than on the average day's work or the hourly rate in Detroit. We are competing in the labor market with persons who pay about 50, 60 and, in some cases, 75 cents per hr. for labor and we make it possible for a man to earn approximately 25 per cent more than at the established hourly rate in Detroit.

MR. GARDNER:—You only come about half-way with the proposition on both those points. It is a compromise proposition.

MR. HASTINGS:—That is true. It would be very satisfactory if a feasible system could be worked out to give the careful owner the benefit of the saving, but we find that the average owner is not interested so much in whether the hourly rate is 75 or 95 cents for a particular job as he is in knowing before the work is started what the total cost will be. Further, we consider this method of charging the owner compares very favorably with the charges for insurance or with street-car fares.

MR. LORD:—Do you give the owner any indication of what the material charge will be?

MR. HASTINGS:—When it is likely that much material will be involved, we tell him that if certain parts are required it will be a certain amount per piece; but, in most cases, we cannot tell.

A. B. CHAMBERS:—You spoke of having a very fast man in your service department who did a 6-hr. job in 2 hr. Did you ever have a man bring in a car and, when he found it ready sooner than he expected because the speed of that particular workman was greater than that of the average mechanic, call you a robber for charging $3 to $4 per hr.?

MR. HASTINGS:—That is easily taken care of, if you watch it. We simply do not deliver the car in that length of time. We have had several of those cases but, at most, they are rare.

MR. GARDNER:—What percentage of the cars that come in have had excellent care?

MR. HASTINGS:—I cannot say as to that.

MR. GARDNER:—You really do not know then exactly how the flat-rate is affecting the owner, whether the man who keeps a car in poor condition is getting the advantage.

MR. HASTINGS:—To my mind, that is more or less an academic proposition. The average time as compared with the minimum and maximum times will not be 25 per cent off from either, except in extreme cases. Suppose a man averages 2 hr. A man who keeps his car in excellent condition possibly could get that job done in 1½ or 1¾ hr.; it might take the man on the other side of the fence 2½ hr. The actual difference in cost is more than made up by the speeding-up all through the organization. Suppose these two jobs were put on a straight-time basis, you would find that, instead of the 1½ hr. that the one job would take under our present system, it would take a full 2 hr. on the straight-time basis; and the job that would take 2½ hr. under our system would probably take 3½ hr. on the straight-time basis. They both win, but the fellow that does not take such good care of his car wins a little more than the other fellow, but they are both ahead of the game, because all the work is speeded-up. Fairness with the owner is a fundamental requisite of all service, if it is good service. We do not tell the owner that the job will take 1½ hr. and then do it in ½ hr.; we do not talk time to him at all; we tell him that a certain job will cost him $1.50 or whatever it may be, and he agrees that that is a fair charge for the work when he signs the order. If there is an impression in his mind that it is not fair, he does not have to sign the order or leave the work with us. It is not like charging him two or three times what the work is worth after it has been done; the price is agreed upon beforehand; if he does not like it, he need not give the order.

A MEMBER:—If a man felt that he were being "gypped" by the flat-rate system, why would it not be right to work on his car by the day and charge accordingly? He would find out in the long run that he was paying more than it would cost the other way.

MR. HASTINGS:—It would be right. We do it on request, but it is seldom requested.

MR. COBLEIGH:—It makes no difference to the mechanic how the car got into a certain condition. The reward of the careful driver is that he does not get into the shop for repairs nearly so soon nor so often as the careless driver. When bearings are worn-out, it is immaterial how they were worn-out; they must be replaced. The old illustration that a bald-headed man pays as much for a hair cut as the man with bushy hair is another answer. I do not believe Mr. Gardner knows how many hours it took to make the suit of clothes he is wearing, and I do not think he cares. The flat-rate is better for the cautious owner as well as the careless owner because the average that both pay on the flat-rate plan always proves to be less than even the careful fellow has to pay on the time-and-material basis.

MR. PLUMRIDGE:—What did Mr. Hastings do in the way of educating his men, in giving them the easiest way to their work, and so on?

MR. HASTINGS:—A blueprint sheet covering each operation was used. We explained to the men in detail what we were trying to do and the inspectors, shop foremen, service manager and myself all have collaborated in getting into the instructions the best methods and the best routine or sequence of operations to do the work properly and with the least effort. When a man, for instance, develops a certain tool, he is rather proud of it, and the foreman soon knows about it. If it is worthwhile, we have one or more of them made and put into the tool crib for the men to draw out as they need them for that operation. I think the whole answer lies in getting the confidence of the men. If the men believe that you think of their interests and want them to succeed and make more money, and you enable them to advance their positions as the opportunities occur, you will

find that they will be more than willing to cooperate; at least, we have found it so. The man who now is our shop foreman came into the organization as a mechanic. He worked for 6 to 8 months as an ordinary mechanic with no promises whatever in the way of preferment before we boosted him into his present job. The two men who act as inspectors at present started in as ordinary mechanics.

MR. PLUMRIDGE:—Do you supply instruction-books to enable the men to do their work more quickly?

MR. HASTINGS:—Nothing except these sheets. Many companies have a bible, as they call it, which, if it is good at all, gradually grows so bulky that the average man does not take the trouble to read it; so, we have avoided anything of that kind. We have tried to make anything we give the men intensely practical.

If a man finds out or thinks that the routine is wrong or that some other way is better, we encourage him to try it, to let the foreman know what he is doing and work it out. If a man finds a method that is better, we cheerfully rewrite the instructions and adopt the new method. When that is done, we put a note on the bottom margin, "Rewritten," and date it to make sure that the later sheets are all distributed. We have a suggestion box and pay from $2 to $5 for each good suggestion. Suggestions of this sort are cashable propositions for the men.

MR. LORD:—When dealing with high-priced cars where the percentage of chauffeurs is high, would you stick to a flat-rate plus material charge? There is a demand, as you have brought out, to know beforehand what the job will cost. When the owner is farther away from the car, as is the case with a higher-priced car with a chauffeur, it is a question whether he would not want a flat figure for the job, parts and labor.

MR. HASTINGS:—That is easily taken care of; you can tell him that the labor will be so much and that the rest will depend on what parts are required, that there will be a maximum figure for parts, and so on. I would not try to make a definite figure for parts before the job is started. I would give a flat figure for labor, so far as I could, except in the case of wreck jobs and work of that kind, and a maximum figure for parts, depending on the nature of the work to be done.

H. N. DAVOCK:—We have a definite charge for the labor required for the inspection to find out how much the material will be, and then we tell the owner definitely what the total charge will be. I think that is necessary in many instances.

MR. HASTINGS:—We have that system, also. We find that it means a telephone call to the owner; he will not wait while you are making the inspection. We do that when an owner wants to know definitely just what the cost will be but, in our experience, the average owner is not concerned so much with the cost of parts as he is with the labor.

MR. DAVOCK:—Why?

MR. HASTINGS:—Because the parts have a fixed price. He knows that if he gets a piston he must pay so much; the price cannot be juggled. We charge the factory list-price plus 5 per cent for parts.

MR. PAGE:—I think you are contradicting yourself, because you have said truly that the car-owner today wants to know how much a repair job will cost. The car-owner does not want the labor and parts separated; he wants to know exactly what the job will cost, complete.

MR. HASTINGS:—If the owner is willing to wait or to depend on a telephone call, we tell him gladly what the complete cost will be, but the average owner will not wait. He wants to get out of the door and to his work in the shortest possible time. Some owners ask us to call back, or they call in the course of an hour or two; in those cases we give the complete price.

MR. DAVOCK:—We find that, on a small job, in 95 per cent of the cases, we can give the cost of labor and material, and that when we get a big job requiring inspection, the owner is anxious to know whether it is a $200 or $300 job, and he wants to know what the material cost will be just as much as he wants to know about the labor charge. The material must be averaged, just as the labor must be averaged now; we believe that this is just as permissible with material as it is with labor.

MR. HASTINGS:—Yes, I think it is permissible. As I have said before, the owner is not interested so much in the actual amount that he must pay as he is in knowing the amount beforehand. If a man wants a new front fender, let us say, we may have to put in some new bolts or a new anti-squeak strip, or something like that, or we may not; 50 cents to $1 will cover the difference; and I think it is entirely permissible as you say, to average the price on that basis.

MR. DAVOCK:—You can average the material closely enough, and then you are exact and do not leave any loop-holes for argument or question.

MR. PLUMRIDGE:—Probably some will doubt whether you put the parts in.

MR. HASTINGS:—We save the old parts and give them to the owner with our compliments.

MR. GARDNER:—It really is a very short step from the ordinary system to the flat-rate system because, on almost all jobs nowadays that amount to $75 or more, you are obliged to submit an approximate estimate. In the last 4 or 5 years, in our service-station, the number of jobs that we have been called on to estimate has gradually increased.

MR. HASTINGS:—You probably spend as much time estimating on jobs as would be required to put in a flat-rate system.

MR. GREENAMYER:—On the write-up sheets that our service salesman has, there is printed, "Do or do not save old parts." It takes about 10 sec. to find out whether the owner wants the old parts saved. If he does, they are put into his car and he takes them away with our compliments. In case an operation can be shortened and a saving effected, do you leave the flat-rate as originally set, or do you give the customer the benefit; if so, what percentage do you keep to cover the overhead and lost production?

MR. HASTINGS:—We have had cases like that. One of them in particular was a rattling in the steering-gear between the control tubes. We devised a tool for expanding the tubes to fit the bushing, rather than trying to ream the bushing to fit the tube. The bushing is thin-walled and the tubes vary in diameter from end to end, so we leave the tube in position, hit the tool with a hammer and expand the tube to fit the bushing; that takes out the rattle. Instead of its being a 2½-hr. job, which it probably would average with new bushings, new tubes and so on, it is about a 20-min. job to take it apart, expand the tube and reassemble it. We have an account that we call "use of special equipment," to which we charge a certain percentage of the saving in such cases. We give the owner about 75 per cent of the saving, take about 25 per cent ourselves and reduce the rates accordingly.

MR. COBLEIGH:—The suggestion about returning the old parts was good but I did not like the expression, "With our compliments." The parts belong to the owner, unless you allowed something for the old parts when you

sold him the new ones. But aside from that, it is a wise thing to do, because it convinces the owner that the parts he bought actually went into the car, and will help to regain the public confidence.

MR. LORD:—The difference between the owner-driven car and the chauffeur-driven car comes up again; that is, the question of how much advantage there is in returning parts to the chauffeur-driven vehicle. With high-priced chauffeur-driven cars, you will find that a large majority of the owners never drive the cars and do not know anything about them.

MR. HASTINGS:—For that reason I think you should go to the owner. We have a man who does nothing but talk to owners part of the time; we do not keep him at that regularly.

MR. LORD:—To discuss repairs?

MR. HASTINGS:—Yes, and to find out whether the car is satisfying the owner; if there is anything that does not satisfy him, to find out about it and take steps to correct it. Certain owners will not come to you; you must go to them.

MR. LORD:—We get along finely with owners who drive their cars; it is those who insist on doing business with us through their drivers that we are more liable to get into more or less serious trouble with.

MR. HASTINGS:—I had an example of that recently; it is not exactly parallel, but is similar. A man bought a sedan last February. He says, and I cannot dispute him although he cannot prove it to me, that he has had constant trouble with his starter sticking. Occasionally a soft flywheel will get through. He says he has had constant trouble for 11 months; yet, the first I heard of it was last week. He is as sore at us as it is possible for a man to be, yet he has not come to us and told us of his troubles. It puts us in a very awkward position. If we had known of this months ago, it would have been a simple matter to fix it and satisfy him; so I say there are certain owners that you must go to instead of waiting for them to come to you.

MR. PLUMRIDGE:—I believe 50 per cent of the trouble could be avoided if you would educate the owner to know something of the work that must be done to the car to put it in serviceable condition.

MR. HASTINGS:—The education of owners, though, is a long and difficult task.

MR. PLUMRIDGE:—If a technical man could talk to those men in such a way that they could understand it, it would help very much.

1922 RETURNS TO AMERICAN FARMERS

A RETURN of $917 to the owner operator for the use of $16,400 of capital and the labor of the farmer and his family during the year 1922 is the average shown by a survey of over 6000 representative farms just completed by the United States Department of Agriculture. These farms average somewhat larger in size and value than the average of the United States, according to the 1920 census.

This return included $715 cash, the margin of receipts over cash outlay, plus an increase of $202 in inventories of crops, live stock and machinery. In addition, the average farm produced food and fuel consumed on the farm, estimated to be worth $294. This $715 cash balance was all the average farm made available to the owner to pay his living expenses and take care of debts.

The results of the operations on individual farms, which make up the average of $917, ranged from a margin of $58,000 of receipts over expenses to a deficit of $34,000 of receipts under expenses. Fourteen per cent of the farms failed to break even, the survey shows. About two-thirds of the farms returned less than $1,000 each. Twenty-eight per cent returned $1 to $500; 23 per cent returned between $500 and $1,000; 14 per cent between $1,000 and $1,500; 7 per cent between $1,500 and $2,000, and only 8 per cent or one farm in every twelve returned more than $2,500 net for the year.

The size of the farms was 252 acres on the average, and the reported value of land and buildings $13,600. The value of crops, live stock and machinery on hand at the beginning of the year was $2,800, making a total capital of $16,400.—*Economic World.*

PETROLEUM PRODUCTS

A REVIEW of refinery production in the United States for a few recent years, covering the four chief petroleum products, shows that the output of gas and fuel oil and of gasoline has made an unbroken advance, while that of the other major products showed a decline in 1922 from the high marks reached earlier. Production in millions of 42-gal. barrels was as given in the accompanying table.

Year	Gas and Fuel Oil	Gasoline	Kerosene	Lubricating Oil
1916	111	49	35	15
1917	155	68	41	18
1918	174	85	43	20
1919	182	94	56	20
1920	211	116	55	25
1921	230	123	46	21
1922	255	148	55	23

So far the supply of fuel oil, although dependent rather upon the production of gasoline than upon the demand for oil, has not limited the extension of its use, except insofar as advancing prices have in some fields placed it beyond the level of competition with coal. For those purposes for which it has special advantages, such as marine fuel, its use will probably continue to be extended. In other fields the use of fuel oil will be determined by the availability and relative cost of coal; here freight and labor charges and the location of deposits will be important factors.—*Commerce Monthly.*

Gear-Grinding and Tooth-Forms

By Glenn Muffly[1]

Detroit Section Paper *Illustrated with* Photographs and Charts

THE production of noiseless gears requires that minute errors in tooth-curves be avoided. Objectionable sound-waves are caused by a gear-tooth error of 0.0003 in. and, as steel cannot be depended upon to go through the heat-treating process and retain so great accuracy as this, the teeth must be ground after they have been hardened; and the grinding operation must be a generating process. The old method of cutting involute teeth with a formed cutter demanded close adherence to the pitch-diameter and no mention was made of the base-circle, which is the basis of modern practice.

After demonstrating the elementary principles involved in the development of the involute curve and showing the relations of the pitch-diameter, the pressure-angle, the pitch and the form of the tooth, and of the base-circles and the pitch-circles and the base-circle tangents that cross at the point of pitch-circle contact, and, similarly, beween the last named and the rack profile with its straight pitch-line, tangent to the two pitch-circles, the author proves that the rack profile moving in synchronism with the pitch-curve will generate the same involute curve as that developed from the base-circle. Consequently, the straight line of the rack tooth is used to generate involute gear-teeth and the cutting tool is moved tangentially at the same velocity as the gear rotation on the pitch-circle. This principle is then applied to hobbing, in which case the gear rotates while the rotation of the hob provides the tangential movement of the tool. The modern process of gear-cutting that is described employs the same principle and has the same relative motion, but it is the gear that moves.

The relative movement between the work and the grinding-wheel is obtained by tapes and segments or circles, the diameter of the segment or circle being the pitch-diameter of the gear less a certain allowance on account of the thickness of the tape, and the effective radius being practically the radius of the segment plus one-half the thickness of the tape. The difficulty encountered due to the variation of the torque as the gear-tooth rolls into and out of engagement with the grinding-wheel is overcome by applying the power to the spindle carrying the gear instead of to the slide.

The method of determining the maximum width of face that can be ground is given and the details of construction of the machine used in grinding by this method are discussed, as is also a gear-testing machine for measuring the microscopic variations from theoretically perfect ground gears, and for showing where and by how much a gear varies from a true involute. Inasmuch as the real test in the prevention of noise is the tooth-to-tooth difference in spacing, which must be uniform, and to provide the greatest possible accuracy, the index plates were obtained from an astronomical dividing-engine.

Changing the relation of the rotation to the slide-travel will modify the tooth-curve. As all modern tooth-forms are based on the involute principle the process described can be used for teeth of a special form, the differences between the tooth-forms being due to differences of the pressure-angle. By eliminating noise, grinding makes possible the use of hardened gears that heretofore could not be made quiet and, likewise, opens the way for greater use of four-speed transmissions that would enable engines to be run within their most efficient range for the greater part of the time. A 6 or 7 to 1 acceleration with a four-speed transmission would be more satisfactory than a 5 to 1 acceleration with direct drive. Quiet gears also are more efficient. Because of the accuracy with which spur gears are now ground it is possible that they will replace helical timing-gears and chain drives.

[1] M.S.A.E.—President, Muffly Mfg. Co., Cleveland Heights, Ohio; sales manager, Lees-Bradner Co., Cleveland.

WE have found in developing our gear-grinding process that objectionable sound-waves were produced by a gear-tooth error of 0.0003 in. To make transmissions that will pass rigid inspection, we must first find this minute error and measure it, and then eliminate it from production. Steel cannot be depended upon to go through heat-treatment and come out so accurate as this. We must, therefore, generate the tooth-curves after the steel has been heat-treated instead of before. I say "generate" advisedly, for it is out of the question to hold formed wheels or cutters within such narrow limits. The only answer, then, is to grind gear-teeth *after* hardening, just as we have for years been grinding many parts of less importance; and the grinding operation must be a generating process.

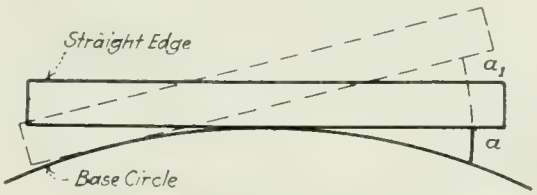


Fig. 1—Diagram Showing How the Involute Curve Is Developed

The purpose of this paper is to show how gear-teeth are being ground within this new limit of accuracy in regular production and how the minute errors in tooth-curves and spacing may be measured. The process goes back to first principles; so we shall start by considering the elementary principles that are more or less obscured in the older processes in which there are one or more steps between the principle and the finished gear.

The involute system was invented before generating machines were available. The old method of cutting involute teeth with a formed cutter demanded close adherence to the pitch-diameter for which the cutter was made in order to reproduce the desired tooth-form. The gear books of that time emphasized the maintaining of the pitch-diameter. All calculations were based on the pitch-diameter and no mention was made of the base-circle at all. Now that we are getting back to first principles and generate gear-teeth from the straight line of a rack tooth we shall have to forget the old ideas and begin to think more about the base-circle diameter.

Involute Curve Development

In Fig. 1 we see how the involute curve is developed. The involute curve on a spur gear is always the involute of a circle. There are involute curves developed from

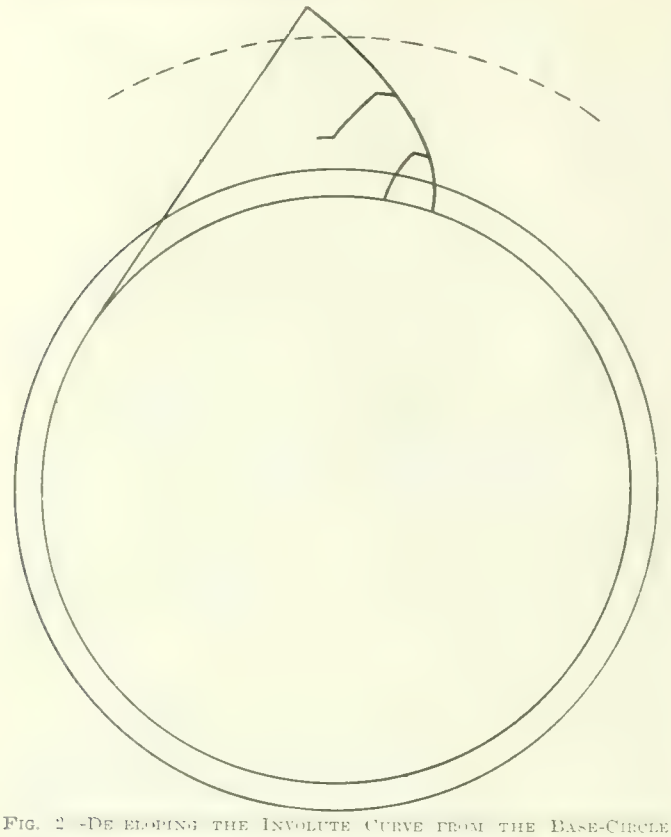


FIG. 2.—DEVELOPING THE INVOLUTE CURVE FROM THE BASE-CIRCLE

other figures, but so far as we are concerned there is only one involute curve, that developed from the base-circle of the gear. When we place a straight-edge in contact with the base-circle and roll it upon the base-circle, any point on the straight-edge will trace the involute of the circle. Tracing an involute curve is similar to "unwinding" it, as it can be traced by unwinding a string from the base-circle, assuming that the string has no thickness.

In Fig. 2 the involute curve is developed from the base-circle, which is always smaller than the pitch-circle. Selecting a pitch-diameter as represented by the larger circle of the two, we use the lower portion of the curve

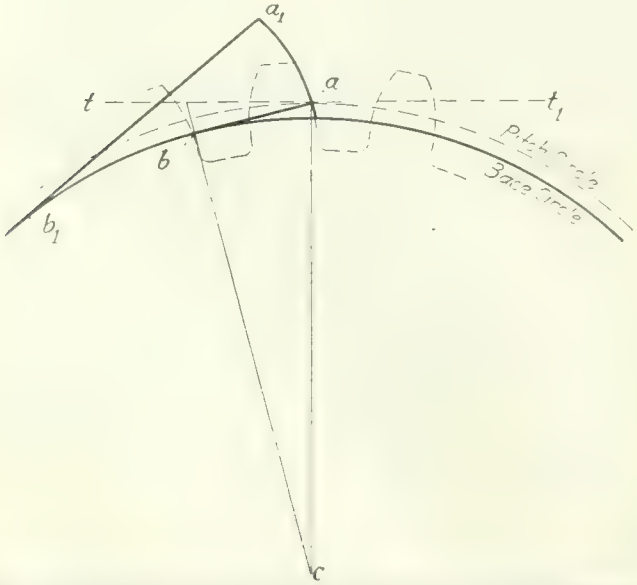


FIG. 3.—DIAGRAM SHOWING HOW THE RADIUS OF THE BASE-CIRCLE IS DETERMINED WHEN THE PITCH-DIAMETER IS KNOWN

in making a tooth as shown, or we can go farther out and construct another tooth of greater pressure-angle, as is indicated. If we were to go still farther out and select a pitch-circle, as is indicated by the dotted line, we should have a still greater pressure-angle. The selection of the pitch-diameter determines the pressure-angle. We can then determine how many teeth we shall put into this circle, thus establishing the pitch of the gear; and we decide how much of the involute curve we shall use above and below the pitch-circle, thus deciding whether the tooth shall be of standard depth, a stub tooth, or of some special form.

In actual practice we are more apt to start with a desired pitch-diameter than with a given base-circle; so we shall proceed as shown in Fig. 3. Starting with a pitch-circle of known diameter we draw the tangent $t\ t_1$.

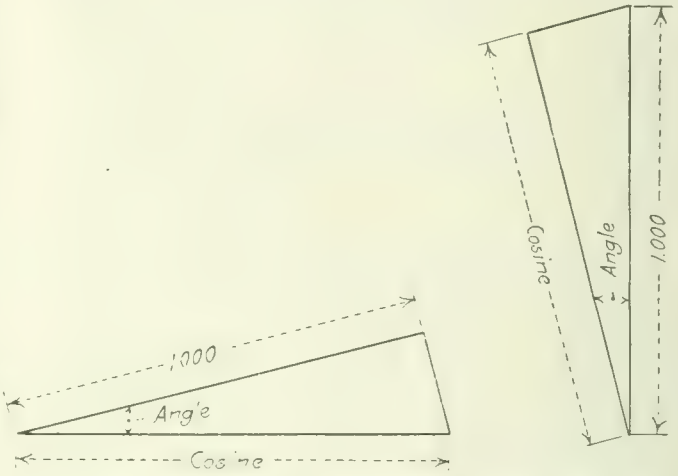


FIG. 4.—DIAGRAMS SHOWING THE RELATION BETWEEN THE PITCH-DIAMETER, THE PRESSURE-ANGLE AND THE BASE-CIRCLE

Next we decide what pressure-angle we shall use, say 20 deg., and we draw the line $a\ b$ at an angle of 20 deg. with the tangent, crossing the pitch-circle and tangent at the point of tangency. Now we drop a perpendicular from the center c to the line $a\ b$ and with the line $c\ b$ as the radius we draw the base-circle. Referring to previous figures, it will be seen that the line $a\ b$ is tangent to the base-circle and the point a will describe the involute curve $a\ a_1$, when the tangent is rolled upon the base-circle. We now have the right-angled triangle $a\ b\ c$ of which we know the side $a\ c$, the radius of the pitch-circle with which we started. We also know that the angle $b\ c\ a$ equals the angle $b\ a\ t$ since each of them is equal to one right-angle minus the angle $b\ a\ c$. Knowing the hypothenuse and one angle of this right-angled triangle we can find the length of the side $b\ c$, which is the radius of the base-circle.

In Fig. 4 we have a diagram showing how this is done. If the hypothenuse is 1, the length of the base-line will be the cosine of this angle. Turning the triangle over and rotating it until its position coincides with the position of triangle $a\ b\ c$ in Fig. 3, we see that the length of the line $b\ c$ is found by multiplying the length of the line $a\ c$ by the cosine of the pressure-angle. Therefore, we have the rule which may be stated as follows; the pitch-diameter multiplied by the cosine of the pressure-angle equals the diameter of the base-circle.

Fig. 5 is a familiar illustration showing the relation of the base-circles and the pitch-circles to the base-circle tangents crossing at the point of pitch-circle contact. Following through the tracing of the involute curves for

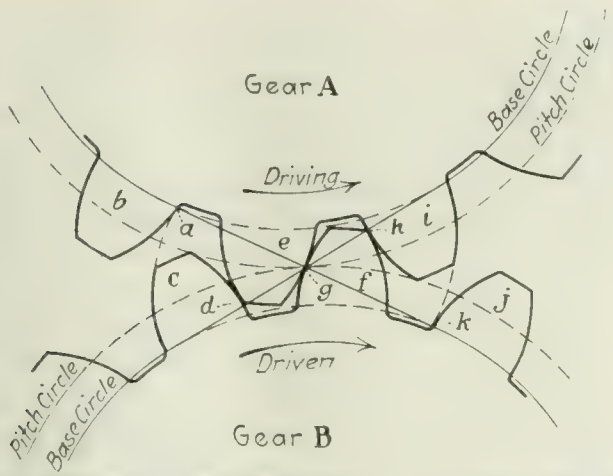


FIG. 5—RELATION OF THE BASE-CIRCLES AND THE PITCH-CIRCLES TO THE BASE-CIRCLE TANGENTS CROSSING AT THE POINT OF PITCH-CIRCLE CONTACT

each side of each tooth of each gear, it will be found that point *a* traces the driving side of booth *b*, also the driven side of tooth *c*, and so on for the other teeth, thus proving that the involute theory is correct.

Fig. 6 is a similar diagram, showing also the rack profile, which has a straight pitch-line, tangent to the two pitch-circles. While the point *l* on the rack pitch-line moves to the point *m*, the same point on the base-circle tangent moves to the point *n*. For any specified amount of angular movement the distance *l-m* will be to the distance *l-n* as *l* is to the cosine of the pressure-angle. It is also shown that the point *n* has not only traced the curves of two teeth but has also traced one side of the rack

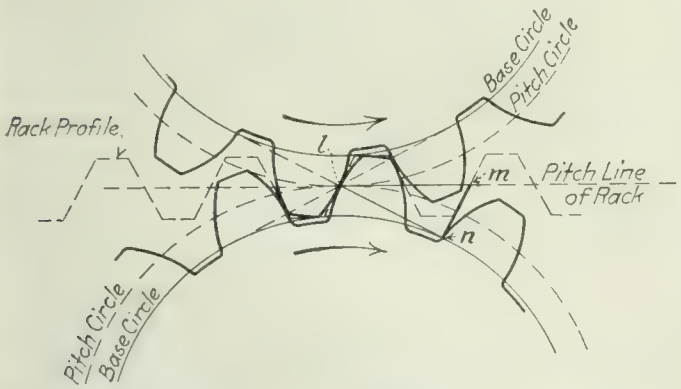


FIG. 6—DIAGRAM, SIMILAR TO THAT REPRODUCED IN FIG. 5, SHOWING IN ADDITION THE RACK PROFILE, WHICH HAS A STRAIGHT PITCH-LINE, TANGENT TO THE TWO PITCH-CIRCLES

tooth, which is a straight line. We can thus prove that the rack profile moved in synchronism with the pitch-circle will generate the same involute curve that we developed from the base-circle. To generate a tooth-curve from the base-circle our cutting-tool would have to be a point and consequently the operation would be very slow. For this reason the straight line of the rack tooth is used to generate involute gear-teeth and the cutting tool is moved tangentially at the same velocity as the gear rotation on the pitch-circle.

In Fig. 7 we see this principle as applied in hobbing. In this case the gear rotates while the rotation of the hob provides the tangential movement of the tool.

GEAR-TOOTH GRINDING

The process of gear-tooth grinding that we use employs the same principle and we have the same relative motion, though it is the gear that moves, as shown in Fig. 8. The grinding-wheel has a flat side which represents one side of a rack tooth. The gear is rolled along on the rack profile and as it rolls into and out of engagement with the grinding-wheel one side of a tooth is finished. Starting from the position *o* the gear rolls past

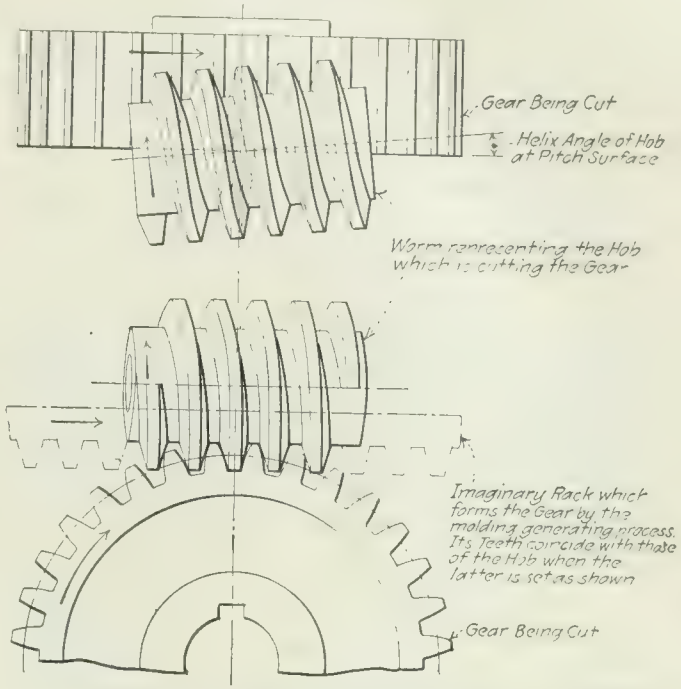

Gear Being Cut
Helix Angle of Hob at Pitch Surface
Worm representing the Hob which is cutting the Gear
Imaginary Rack which forms the Gear by the molding generating process. Its Teeth coincide with those of the Hob when the latter is set as shown
Gear Being Cut

FIG. 7—DIAGRAM ILLUSTRATING THE PRINCIPLE OF THE HOBBING PROCESS FOR FORMING SPUR GEARS

the wheel to the position *p*, reverses and rolls back to the position *o* thus passing over the wheel twice. The gear is automatically indexed at this point and the next tooth is rolled over the wheel twice. This operation continues until the gear has made a complete revolution, or in some cases two complete revolutions.

When the gear is first placed on the machine it is

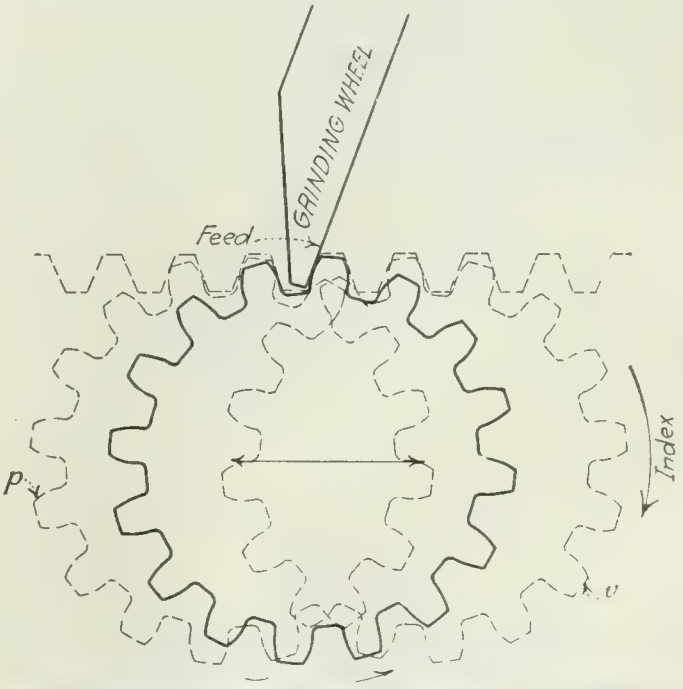


FIG 8—APPLICATION OF THE HOBBING PRINCIPLE TO THE GRINDING OF GEAR-TEETH

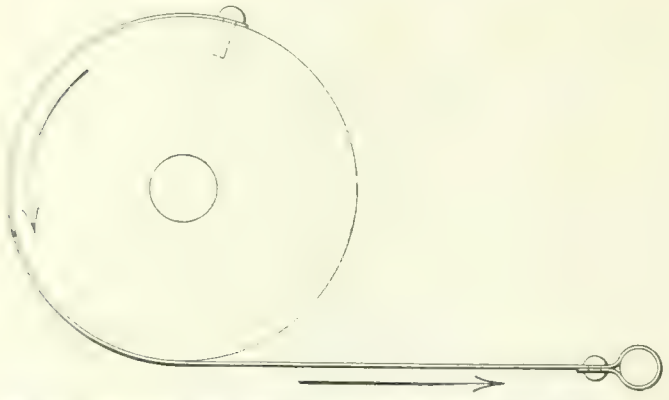


FIG. 9—HOW THE RELATIVE MOVEMENT BETWEEN THE WORK AND THE GRINDING-WHEEL IS OBTAINED BY TAPES AND SEGMENTS OR CIRCLES

locked into position so as to register with the grinding-wheel; then the grinding-wheel is moved in the direction marked "Feed" by whatever amount is allowed for the grinding finish. The wheel is 30 in. in diameter, so it is not necessary to dress the wheel during the process. The dressing is done between the gears at intervals of from one to six gears, depending on the size of the gear and

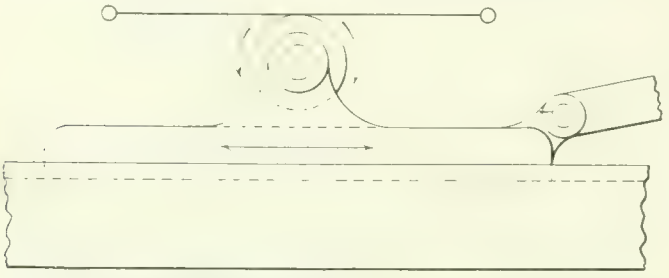


FIG. 10—THE OLDER METHOD OF APPLYING THE TAPE AND SEGMENT PRINCIPLE

the amount of metal removed. Since we are using the flat side of the wheel it is necessary only to move the diamond at right angles to the axis of the wheel to maintain this flat surface. In order that the dressing shall not change the relative positions of the wheel and the work, this operation is performed by moving the wheel up to the diamond instead of moving the diamond up to the wheel.

The relative movement between the work and the grinding-wheel is obtained by tapes and segments, or circles, as shown in Fig. 9. The diameter of the circle or segment is the pitch-diameter of the gear, less a certain allowance on account of the thickness of the tape. The effective radius is practically the radius of the segment, plus one-half the thickness of the tape.

Fig. 10 shows the older method of applying this principle. The slide carrying the work was moved longitudinally while the ends of the tapes were secured to fixed points, thus obtaining the rotation from the longitudinal movement.

Fig. 11 illustrates the difficulty encountered. As the gear-tooth rolls into and out of engagement with the grinding-wheel a variaion in the torque is required to rotate the gear, and this variation of the load on the tapes produces a slight variation in the relative angular-velocity. When working within such close limits as are necessary to make a spur gear really quiet we cannot afford to let even such a slight error as this pass. The resulting error is shown in exaggerated form by the inserted tooth-profile at the left.

Our method of overcoming this difficulty is shown in Fig. 12. Power is applied to the spindle carrying the gear instead of to the slide. The frictional resistance to the slide movement is constant, since it is governed by gravity alone. The acceleration and the deceleration of the slide movement occur while the gear is not in mesh with the grinding-wheel.

The two tapes are attached to a tape-bar supported by

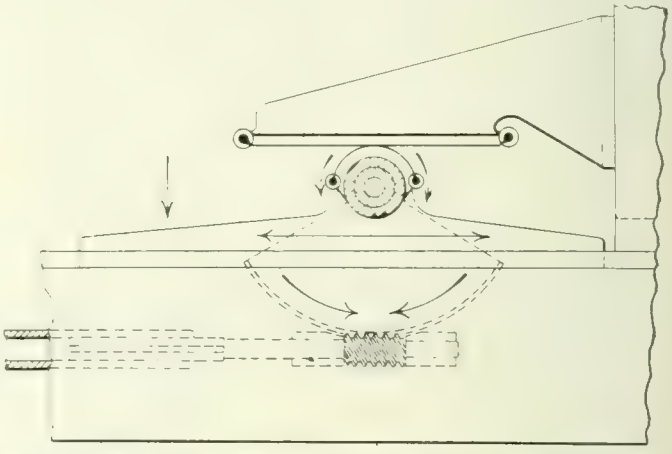


FIG. 12—APPLYING POWER TO THE SPINDLE CARRYING THE GEAR INSTEAD OF THE SLIDE CARRYING THE GRINDING WHEEL IS RELIED UPON TO OVERCOME THE DIFFICULTY ILLUSTRATED IN FIG. 11

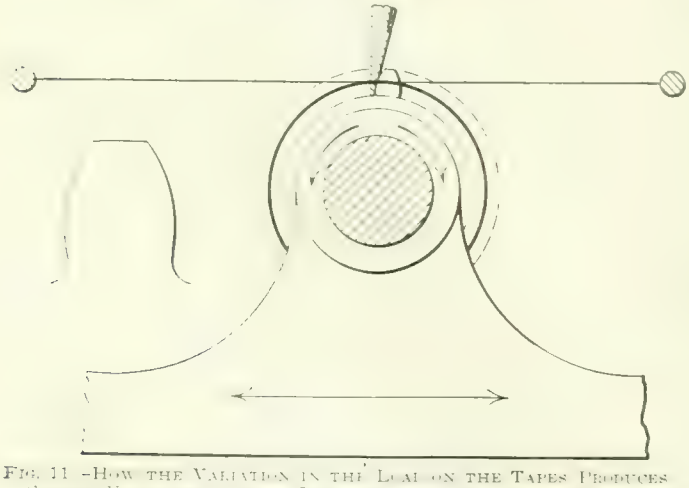


FIG. 11—HOW THE VARIATION IN THE LOAD ON THE TAPES PRODUCES A SLIGHT VARIATION IN THE RELATIVE ANGULAR VELOCITY OF THE WORK AND THE GRINDING WHEEL
This Slight Error, Which Is Shown in an Exaggerated Form by the Tooth Profile at the Left, Produces a Noisy Gear

a heavy overhanging head, as shown in Fig. 13. Vertical and horizontal adjustments are employed only in setting-up.

In Fig. 14, which shows an elevation of the complete machine, we can see these various elements in relation to one another. The spindle that carries the grinding-wheel is arranged to swivel for various pressure-angles and the saddle that carries it has a vertical adjustment for various diameters of work.

The relation of the grinding-wheel to the gear is shown again in Fig. 15. The angle of the grinding surface with the perpendicular is equal to the pressure-angle; in other words, the angle between the grinding-wheel spindle and the direction of work-travel is the pressure-angle. On account of the large diameter of the grinding-wheel it is not necessary to travel the wheel along the axis of the gear.

Fig. 16 shows the longitudinal section of the work-spindle as viewed from the front of the machine. On the

left we have the index mechanism, in the middle the tapes and the segments and at the right the gear that is being ground. The arc of the grinding-wheel is shown in part. The indexing is obtained from hardened steel plates, a different plate being used for each number of teeth. In setting-up the machine we put on the proper index-plate for the number of teeth, the segment and the tapes for the required pitch-diameter and a suitable arbor or fixture for holding the gear. The grinding-

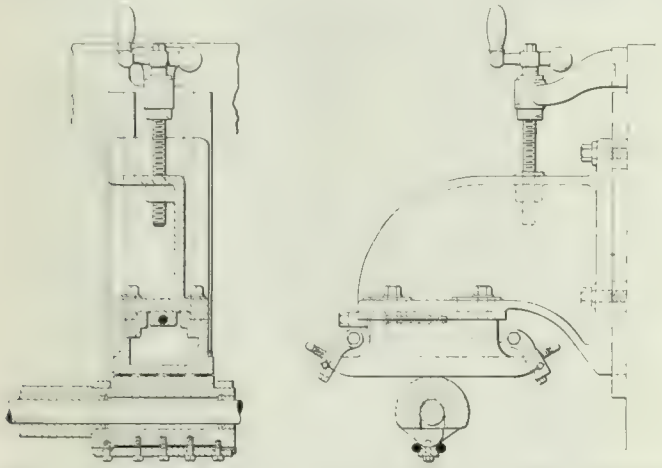


FIG. 13—METHOD OF ATTACHING THE TAPES TO A TAPE-BAR THAT IS SUPPORTED BY A HEAVY OVERHANGING HEAD

wheel spindle is then set at whatever pressure-angle we wish to grind and the head is adjusted vertically for the diameter of the gear. The grinding-wheel is not changed,

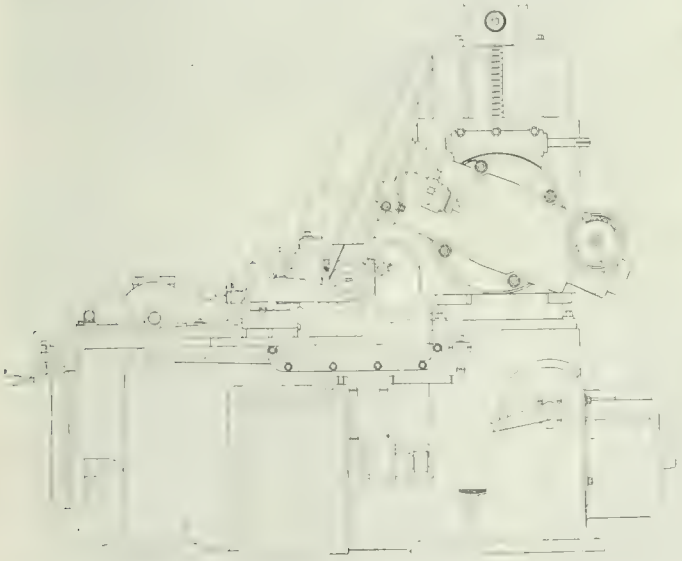


FIG. 14—ELEVATION OF THE COMPLETE GEAR-GRINDING MACHINE

as all pitches and pressure-angles are ground with the same flat surface.

Fig. 17 shows how to determine the maximum width of face that can be ground. It is, of course, necessary that the wheel should clear the full depth of the gear in the middle of the face, or the points r and s in the case of two gears with a space between them, and that the wheel should come down to the full working depth at points t and u. On a six-pitch gear of standard clearance we can grind $1\frac{3}{4}$ in. of face. If it is necessary to grind a wider face the gear can be roughed-out with more clearance at the bottom to allow for setting the wheel in to the required depth.

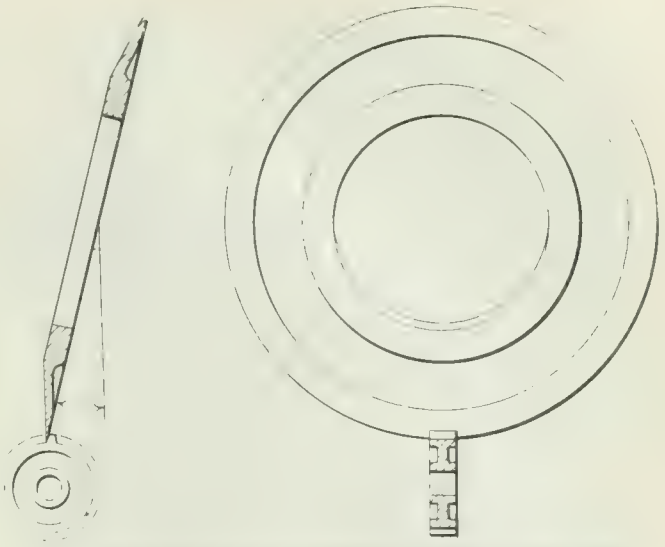


FIG. 15—RELATION OF THE GRINDING WHEEL TO THE GEAR

At the left of Fig. 18 is a view of the machine as seen by the operator, while the other portion of the illustration is a rear view of the machine showing the drive-pulley, the housing over the index mechanism at the end of the work-spindle, and the gearbox that controls the

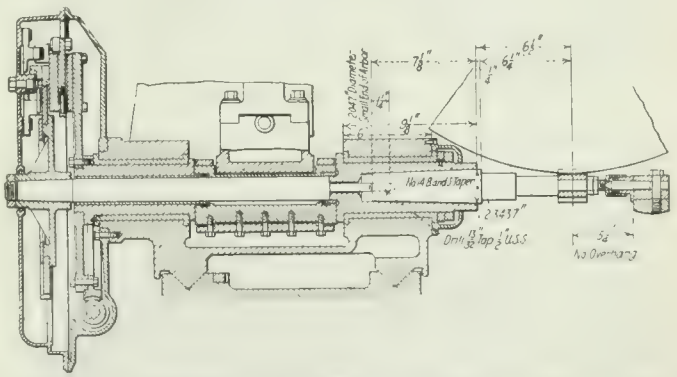


FIG. 16—A LONGITUDINAL SECTION OF THE WORK-SPINDLE AS SEEN FROM THE FRONT OF THE MACHINE

rotation of the work, and through this, by means of the tapes, the travel of the table.

A foot-brake on the grinding wheel spindle is used to save time in stopping the machine. The tape-clamps and the tighteners are mounted on the tape-bar to which I have referred. Other features include the segment-roll

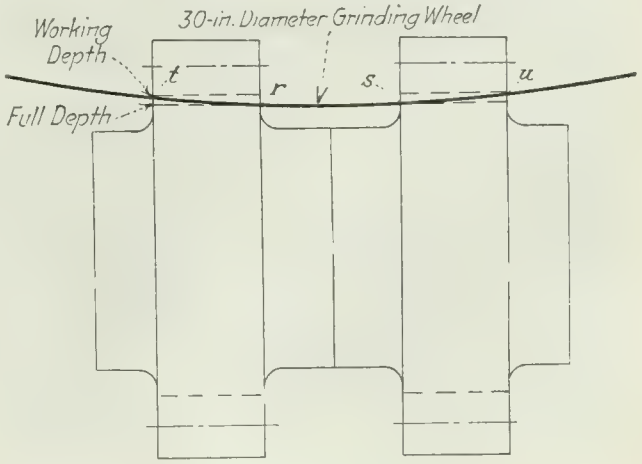


FIG. 17—DIAGRAM SHOWING HOW THE MAXIMUM DEPTH THAT CAN BE GROUND IS DETERMINED

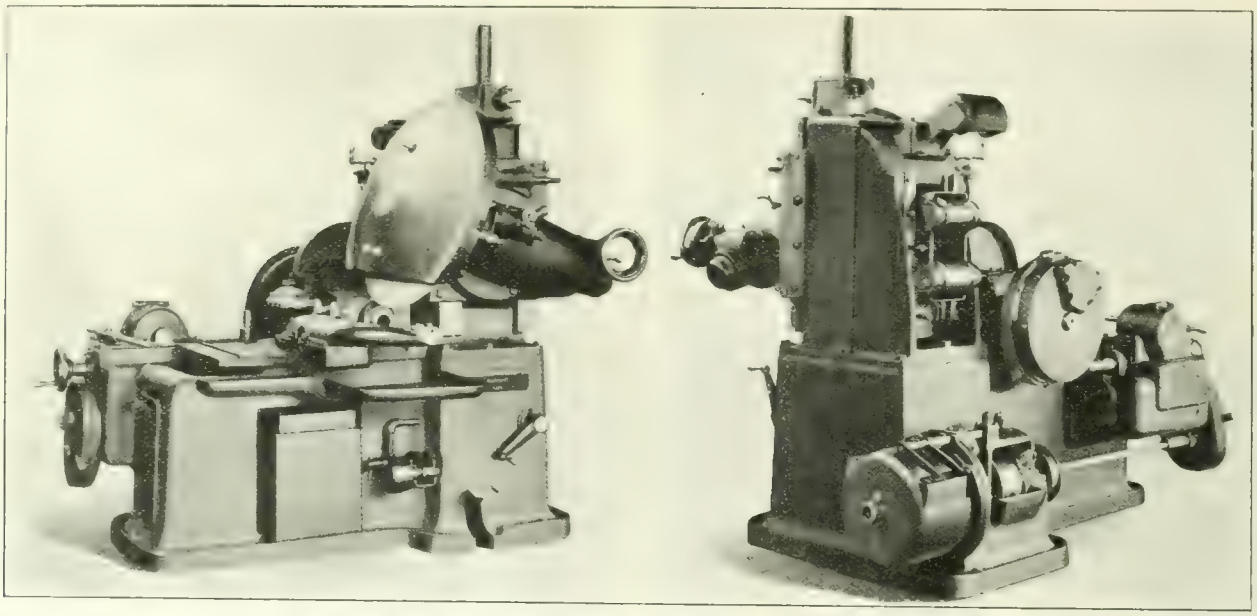


FIG. 18—SIDE AND REAR VIEWS OF THE GEAR-GRINDING MACHINE

on which is mounted the segment on which the tapes are wound; the indexing mechanism that automatically indexes the gear from tooth to tooth between passes over the wheel; the adjustable stops for varying the travel of the carriage, located in a housing in front of the index mechanism and directly above the gearbox for controlling the speed of the carriage; and the handwheel for actuating the carriage, which is used only in setting-up the machine.

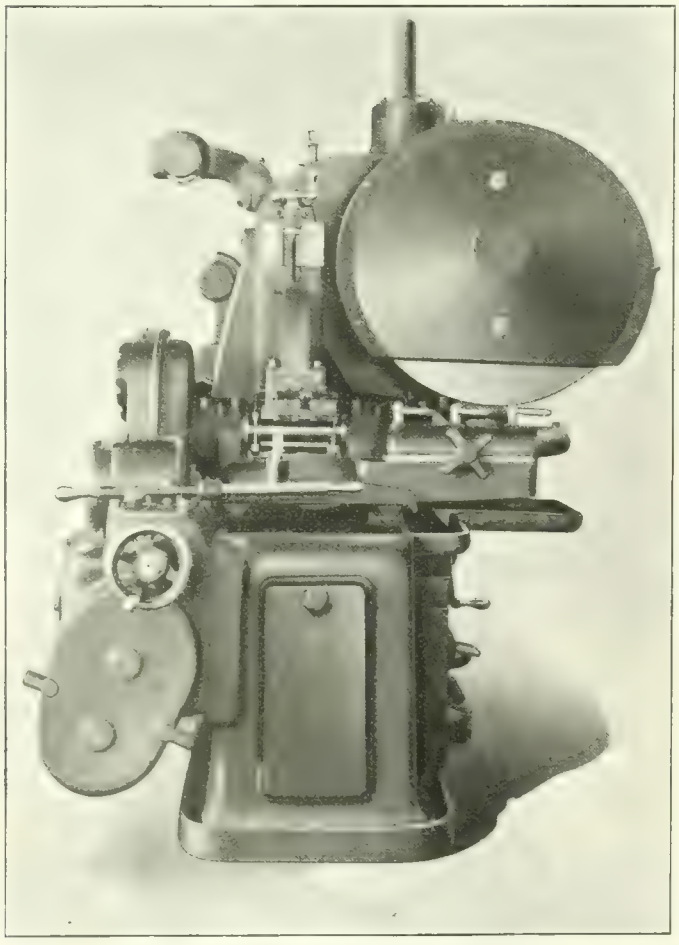


FIG. 19—FRONT VIEW OF THE MACHINE

Fig 19 is a front view of the same machine.

Fig. 20 shows the grinding-wheel head. At the left side is the ball-crank that actuates the diamond by a worm and worm-gear. The adjustable diamond-holder is carried by a crank on the worm-gear shaft and the diamond itself is adjusted against a hardened-steel block that definitely establishes the plane of the grinding-wheel surface. The handwheel, shown at the lower right-hand side, is used for the dressing that is accomplished by feeding the wheel up to the diamond. It is provided with a stop that moves as the wheel is dressed, so that in making the setting for any gear the wheel always stops in the same plane.

The worm and worm-gear adjustment above the spindle is used in setting the head at the pressure-angle as shown on a vernier dial. If the operator should set the head at the wrong angle he will grind a different pressure-angle but will keep the correct pitch-diameter. Such an error would show-up at once when testing the gear on the machine shown in Fig. 21.

Since this process is based entirely on elementary principles employing straight lines and circles instead of master forms of any kind, it is much easier to hold production to an exact standard than when the accuracy depends on outside sources. The process and the operation of the machine are simple enough to be placed in the hands of unskilled operators, but, of course, the supervision and the inspection should be in competent hands.

TESTING GEAR-GRINDING ACCURACY

Fig. 21 is a general view of the gear-testing machine that we found it necessary to design to measure the microscopic variations from theoretically perfect ground gears.

At the left of Fig. 22 is a top view of the machine before the gear is placed on it. A disc is ground to the base-circle diameter and placed on the work-arbor. The tangent-bar, or straight-edge, is held against the base-circle by the two ball-bearings on the slide-frame under spring tension. As the slide-frame is rotated upon the work-arbor the tangent-bar rolls about the base-circle and the point of the contact-lever traces the involute.

The central portion of the illustration shows the gear to be tested in place. If the tooth-curve is a perfect involute the indicator will stand at zero while the contact-point travels from the base-circle to the point of the tooth. The graduations on a cross member of the slide-frame, just below and to the left of the indicator, comprise a travel-scale showing the progress of the point of tangency upon the tangent-bar, and therefore the progress of the contact-point toward the point of the tooth. These are purely arbitrary graduations and need have no numerical unit assigned to them. On a given tooth we find, for instance, that 21 graduations represent the travel from the base-circle to the point of the tooth and we can tabulate a record showing the deviations of the indicator, plus or minus, at each of these lines. In this way we can plot a curve showing where the tooth is high and where it is low. The indicator reading is in tenths of thousandths.

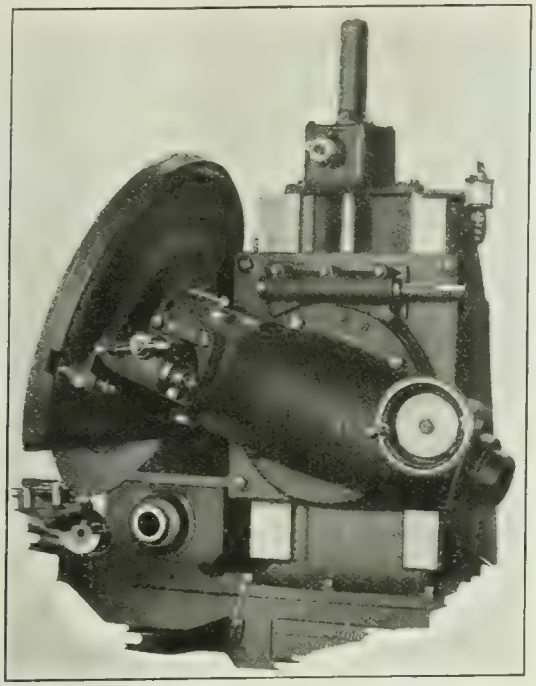


FIG. 20—VIEW OF THE GRINDING-WHEEL HEAD

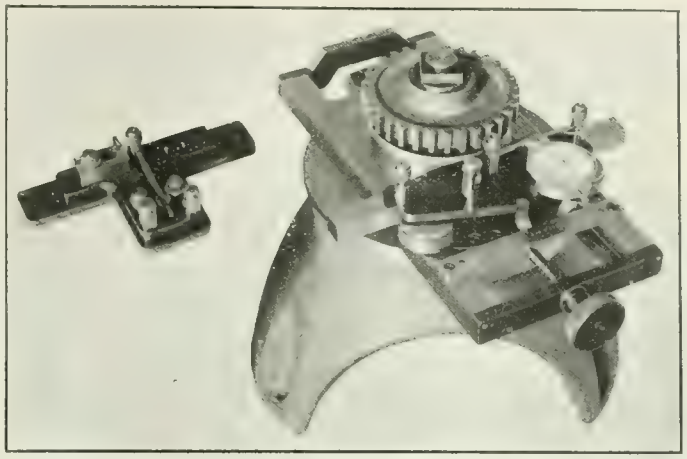


FIG. 21—GENERAL VIEW OF A MACHINE THAT HAS BEEN DEVELOPED TO MEASURE MICROSCOPIC VARIATIONS IN GEARS

There are a number of other methods of testing gear-tooth curves but we have found this method to be most satisfactory for use in connection with our gear-grinding machine because it is necessary to obtain definite measurements. It is not enough to know that a gear-tooth is good or bad; we want to know where and by how much it varies from the true involute. If the gear has a greater or a lesser pressure-angle than the one intended, this fact will show-up at once in a very definite way. It is particularly important that we shall be able to tabulate deviations from the true involute at various points on the tooth because we have found that the perfect involute does not make the most quiet gear. This may seem to contradict my statement, in connection with Fig. 5, that the involute curve is theoretically correct.

TOOTH-SPACING

Carrying the theory just a little farther, it is obvious that we want a true involute curve while the gear is under load, not while it is on the testing-machine. We are working with such minute errors that we must take into consideration the deflection of the tooth under load and

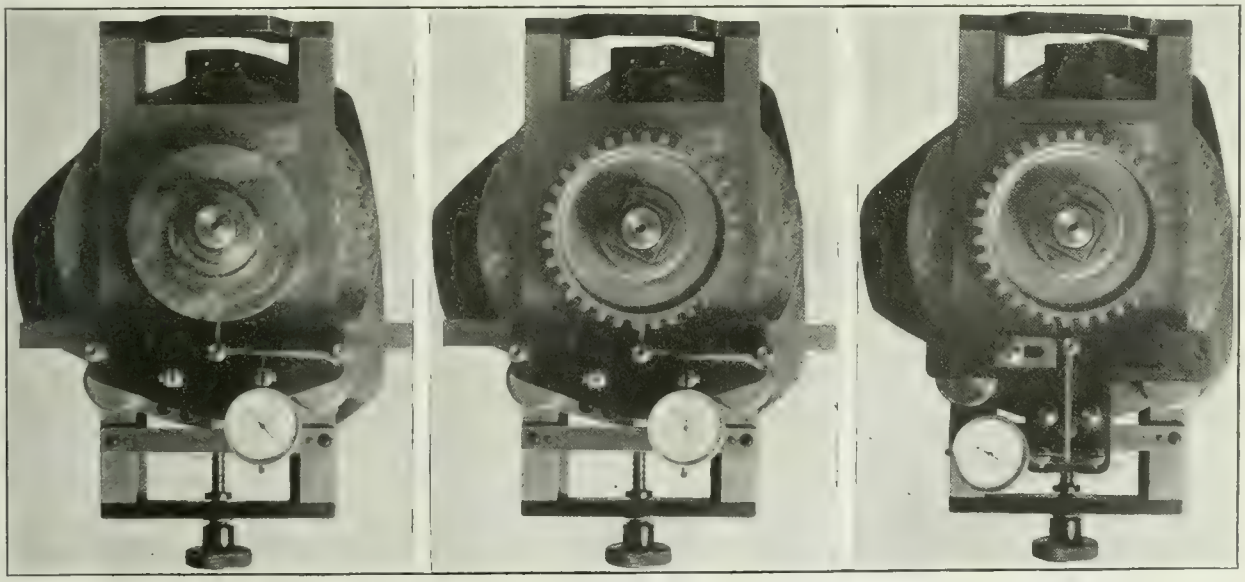


FIG. 22—A SERIES OF VIEWS OF THE GEAR-TESTING MACHINE
From Left to Right These Are a Top View of the Machine, the Machine with the Gear in Place and the Machine Arranged To Test Tooth-Spacing

modify the tooth-curve to compensate for this deflection. When the right modification has been found and the results have been tabulated we can reproduce this modified curve consistently, and with the testing-machine we can check our product to see that we are holding to the desired curve.

The right portion of Fig. 22 shows how this same machine is set-up for testing the tooth-spacing. The indexing fixture, shown at the side in Fig. 21, is placed on the machine and locked into position by bringing the screw tension up against the base-circle. This fixture does not move on the base-circle and is locked into position on the slide-frame. The fixed tooth-stop at the left is clamped into position to make contact with one tooth while the next tooth engages the point of the contact-lever. On the first space the indicator is set at zero; the gear is then lifted out of engagement with the stop and is rotated one tooth. As each successive tooth is brought against the stop the indicator reading is noted. It shows tenths of thousandths, plus or minus, from the setting on the first space, and when we get back to the first tooth again the indicator should have a reading of zero, which shows that nothing has been moved during the test. Similar tests sometimes are made by indicating over several teeth or half-way round the gear, but the real test in the prevention of noise is the tooth-to-tooth difference in the spacing. For instance, we might have a gear on which the readings start at zero on the first tooth, with plus 0.0001 in. on the next tooth, plus 0.0002 in. on the third and so on, half-way round the gear, and then decrease 0.0001 in. on each tooth back to the first tooth. This would be a good gear because the tooth-to-tooth difference in spacing is only 0.0001 in., but if we tested it for the cumulative error half-way round the gear and happened to select the same starting-point, we should get an error of 0.0020 in. on a 40-tooth gear. Another gear might show no error when tested half-way round, but there might be an error of 0.001 or 0.002 in. between two adjacent teeth when tested as shown here. This would not be a good gear.

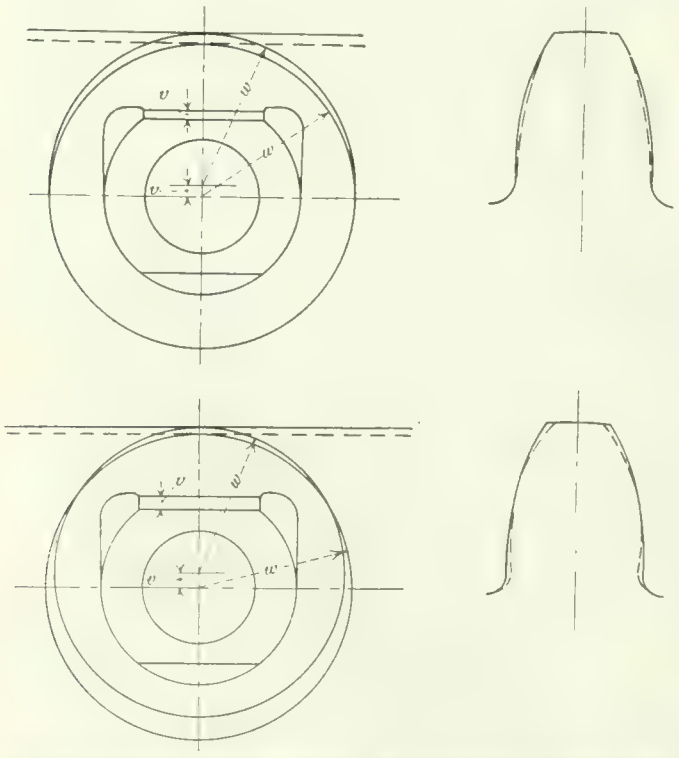


Fig. 23—Drawings Illustrating the Two Methods of Modifying the Tooth Curves

The Upper Arrangement Gives a Tooth That Is Low in the Vicinity of the Pitch-Line, While with the Other the Tooth-Curve Is Low at Both the Point and the Root

After developing this process to the point of obtaining involute curves that were practically perfect, we found that no existing method of indexing was accurate enough to go with such tooth-curves and it was necessary to devise new means for indexing on the machine as well as new means for obtaining master index-plates. The indexing of the master plates now used was obtained from an astronomical dividing-engine, said to be the most accurate machine of its kind in the world.

Modification of Tooth-Curves

In connection with the modification of tooth-curves, we see in the upper part of Fig. 23 one of the methods of accomplishing this. Any change in the relation of the rotation to the slide-travel will produce a modification in the tooth-curve. By controlling the change in the relative motion we can control the change in the tooth-curve. This view shows how the shim v is placed under the segment without changing the radius w. This produces a tooth that is low in the vicinity of the pitch-line. The lower part shows another modification using a radius, smaller than the standard, that makes the curve low at the point and low at the root of the tooth. These modifications are very minute when compared with the modifications that have been made in the past. The tooth-form that we recommend is so near to the true involute that it would pass for a perfect involute curve when tested by any of the ordinary methods.

We are often asked if this process of grinding will produce gear-teeth of a special form. The answer is yes, so far as any of the well-known tooth-forms of today are concerned, for they all are based on the involute principle. A modication of the clearance at the bottom of a tooth is, of course, a matter entirely aside from the question of the curve on the working surface of the tooth. The differences between these various tooth-forms are only differences of the pressure-angle; in other words, various persons recommend various portions of the same involute curve.

Fig. 24 may appear somewhat startling at first sight, for it shows a gear on which four different pitch-diameters and four different pressure-angles are specified. It has been hobbed at a 20-deg. pressure-angle, and meshes with three gears having a pressure-angle ranging from 18 deg. 37 min. to 22 deg. To make these three mating gears look right we had to put long addenda on two and a short addendum on one of them. The set-up to grind all four gears will be identical, for they all have exactly the same involute curve.

The only difference is that we use a different part of the involute curve on each of the four gears. On the pressure-angle of 18 deg. 37 min. we go down a little closer to the base-circle, and on the 22-deg. pressure-angle we go up a little higher from the base-circle. If we have a pair of 20-tooth five-pitch gears with a 20-deg. pressure-angle, and we mesh these gears on a center-distance of 4.040 in., the gears will be running at a pressure-angle of 21 deg. 30 min. The starting-point is the base-circle, not the pitch-diameter. If the gears have a 20-deg. pressure-angle at a 4-in. pitch-diameter, they will have a base-circle diameter of 3.7588 in., and whenever we go out on the involute curve and establish a new pitch-diameter we can find our pressure-angle by going back to the base-circle, not to the old pitch-diameter. Dividing our base-circle diameter by the new pitch-diam-

eter, 4.040 in., we get 0.93039, which is the cosine of 21 deg. 30 min. 16 sec.

Going back to the four gears shown in Fig. 24, we could set the grinding-wheel at 21 deg. 30 min. and grind all four gears at a 4.040-in. pitch-diameter; we could set the grinding-wheel at 18 deg. 37 min. and grind all four gears at a 3.925-in. pitch-diameter, or we could set the grinding-wheel at a 22-deg. pressure-angle and grind all four at a 4.054-in. pitch-diameter. In each case we should get exactly the same results as if we had used the original 20-deg. pressure-angle on a 4-in. pitch-diameter. Each of the four gears is developed from a 3.7588-in. base-circle.

If you ever have had a pair of gears that were a little tight and you have spread the centers so that they would run better, you have in effect produced a new tooth-form, and if the pressure-angle happened to work-out to 14 deg. 37 min., or 20 deg. 13 min., you might tack your name on that particular pressure-angle and call it your tooth-form. We recently discovered a manufacturer, not 1000 miles from here, who has been cutting gears at 15-deg. 16-min.-pressure-angle for years and did not know that they did not have a 14½-deg. pressure-angle until he started to grind the gears and checked up the tooth profile by the test shown in the central view of Fig. 22.

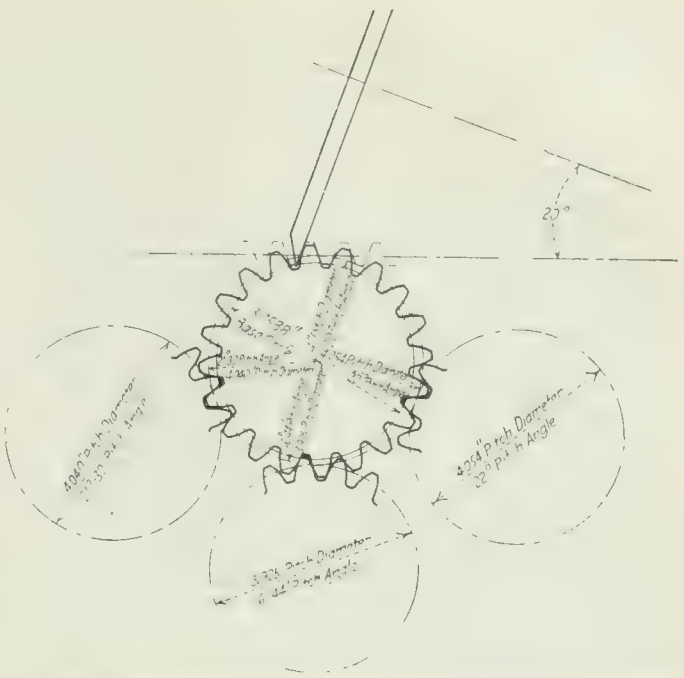


FIG. 24—DIAGRAM SHOWING HOW A GEAR THAT IS GROUND AT ONE PRESSURE-ANGLE WILL MESH WITH THREE OTHERS EACH OF WHICH HAS A DIFFERENT PRESSURE-ANGLE

PITCH-DIAMETER

I have made a working model which will illustrate this sameness of the involute curve for all gears better than I can do it with a drawing. The point I wish to make is that an involute gear has no pitch-diameter of its own and acquires a pitch-diameter only when it is meshed with another gear, or with a hob, a cutter or a grinding-wheel. Consider the gear in the center of Fig. 24. First we grind it by setting the wheel at a 20-deg. angle and using a 4-in. pitch-circle; while grinding it has a 4-in. pitch-diameter; then we take it off the machine, whereupon it loses its pitch-diameter. If we mesh it with the gear on the left, on a center-distance of 4.040 in., immediately the gear acquires a pitch-diameter of 4.040 in. and runs at a pressure-angle of 21 deg. 30 min. If we take the same original gear and mesh it with the gear at the right, or with another gear exactly like it on a center-distance of 4.054 in., both gears immediately acquire pitch-diameters of 4.054 in. and run at a pressure-angle of 22 deg. If we mesh it with the gear at the bottom on a center-distance of 3.925 in., we find that both gears have pitch-diameters of 3.925 in. and run at a pressure-angle of 18 deg. 37 min.

The first thing I learned about a gear had to do with the pitch-diameter and I grew up in the belief that the pitch-diameter was the starting-point, whereas in reality there is nothing at all stable about the pitch-diameter. A pair of involute gears running on a center-distance 0.010 in. greater than the standard are running just as accurately theoretically as if they were meshed on the center-distance for which they were originally intended, except, of course, that a pair of gears to be run in this way should have the teeth cut a little thicker to keep the backlash within reason.

The device at the extreme left of Fig. 25 is a working model of the diagram shown in Fig. 5. The center-distance is 16 in. and the two base-circles are of the proper diameter to give us a 20-deg. pressure-angle. The distance from the center of the smaller gear to the point at which the tapes cross is to the distance from the center of the larger gear to this point as the diameter of the smaller base-circle is to the diameter of the larger base-circle. No matter to what center-distance we move these base-circles, there respective centers will be proportionately distant from the point of tape-crossing.

We attach a pencil *A* to one of these tapes so that it

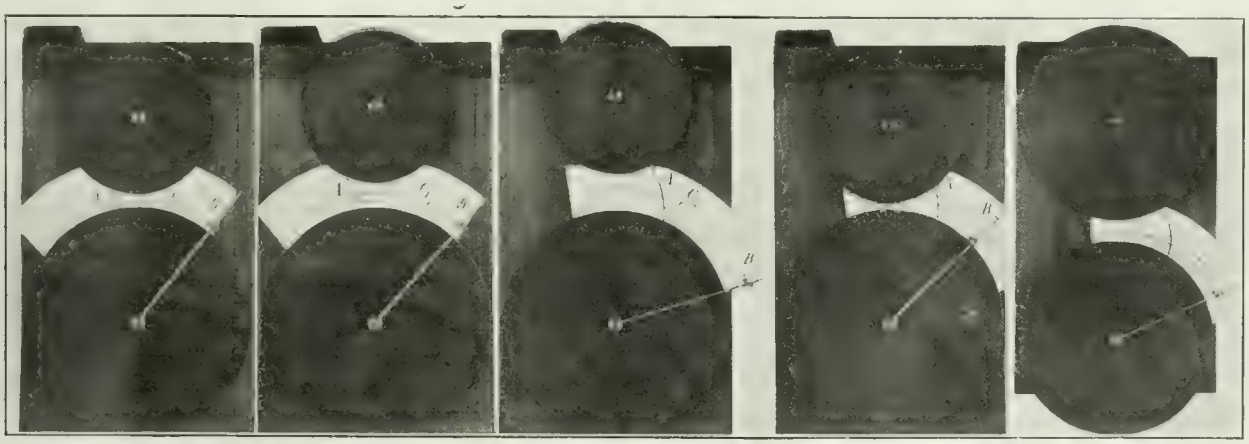


FIG. 25—DEVICE ILLUSTRATING THE SAMENESS OF THE INVOLUTE CURVE FOR ALL GEARS

will trace the involute of the larger base-circle on the sheet of paper attached to the base-circle. We use a tooth-curve of 20-deg. pressure-angle because the base-circles are located at a definite center-distance which establishes a definite pitch-diameter for each gear. With the compass-bar B we strike the pitch-circle C of the larger gear. If a similar sheet of paper were attached to the smaller gear we should also draw its pitch-diameter through the point of tape-crossing; in other words, the two pitch-circles touch at the point where the two base-circle tangents cross. So far this operation follows the well-known elementary principles of involute gearing.

Let us change the center-distance and see what will happen to the tooth-curve when we move the smaller base-circle one hole up to a center-distance of 17 in., as in the second illustration from the left. We now have a center-distance of 17 in. with the same old base-circles. This center-distance will give a pressure-angle of 27 deg. 49 min. We now draw a tooth-curve of this pressure-angle for the larger gear. The tooth-curve for the gear will have a 27-deg. 49-min. pressure-angle. You will observe that it is the same curve, only a little more of it. We now have the arc C_1, a new pitch-diameter for the larger gear, and we have a proportionate increase in the pitch-diameter of the smaller gear.

Let us increase the center-distance once more, shifting the smaller base-circle upward to the last hole, which makes the center-distance 18 in., as in the middle view. We have now a center-distance of 18 in. and can use some more of the involute curve. This is still the same old tooth-curve, but the pitch-diameter is a little farther out from the base-circle, that is, the arc C_2, of the new pitch-circle. At this pitch-diameter we have a pressure-angle of 33 deg. 21 min. Somewhere on this curve you will find any special tooth-form in which you are interested.

If we go back to a smaller center-distance than the one with which we started, by shifting the smaller base-circle down to the bottom hole, as in the first view to the right of the center, we get our old friend, the 14½-deg. pressure-angle.

If the center-distance is exactly 15.5296 in., we shall have a pressure-angle of exactly 14 deg. 30 min. You will note that we are still using the same involute curve, but we go only a little way up from the base-circle. You will readily appreciate that I could have changed the pressure-angle by changing the base-circle diameter instead of changing the pitch-diameter.

I have found that most mysteries of involute gearing dissolve when gear problems are attacked directly from first principles. I hold no brief for any particular pressure-angle; there are cases in which we recommend large pressure-angles and other cases in which we recommend small pressure-angles. In all cases you must reproduce the tooth-form accurately so that the gears finished today will mesh with those finished next week and with those finished next year. The closer you can keep the process to the elementary principles, which are based entirely on straight lines and circles, the easier it will be to reproduce any given tooth-form in quantities.

It is logical that gear-teeth should be finish-ground after heat-treatment. We should not think of letting a cam go without grinding; and every gear-tooth is a cam. It moves at a higher velocity and under greater pressure than the cams that operate the valves.

Gear-Noise

A big item in the cost of transmission production is the tearing-down and reassembling of gearboxes on account of gear-noise. This cost often extends beyond the transmission department to the chassis-assembling department and even to the finished cars after shipment. These items of cost are entirely eliminated by the finish-grinding of the gear-teeth after heat-treatment, provided, of course, that proper standards are adhered to and the gears are tested for tooth-form and spacing before assembling. In some cases it has been shown that the saving in assembling costs, inspection and rejections was greater than the additional cost of grinding, when compared with those of previous methods.

Automobile design has been seriously handicapped by the lack of a process for generating gear-teeth after hardening. This new process not only eliminates gear-noise, but the designing engineer can do things he never dared do before because hardened gears could not be made quiet. One passenger-car builder, among those who recently have adopted gear-grinding, is now working on a four-speed transmission. With four-speed transmissions, engines can be run within their most efficient range for the greater part of the time. The public now hesitates to use change-speed gears because it does not like the noise. The man whose car accelerates quickly on a 5 to 1 direct drive will be more than pleased with the acceleration he will get at 6 or 7 to 1 with a four-speed transmission. Take a list of passengar-car specifications for 1923 and check their rear-axle ratios; then figure how many revolutions the rear wheels must make in a mile and how fast the engine must run to make 30 m.p.h. There are many cars in which the engines would have to run at 4000 to 5000 r.p.m. to make the speeds that salesmen claim for them.

The grinding of gear-teeth opens up possibilities for a really high fourth-speed and a smoothness of operation in traffic that the one-speed driver never has experienced. We shall see four-speed jobs and we may see transmissions in which there is no direct drive, thus making all speeds uniformly efficient. Getting the propeller-shaft on another and a lower center permits lowering the body floor and reducing the angle of universal-joint operation.

Quiet gears also are more efficient. The improvement in fuel economy that is accomplished by using the most efficient gear-ratio under all driving conditions will more than offset any loss of power in the gears, particularly when the gears are really efficient.

Transportation cost by truck is being given more attention on a ton-mile basis than is the transportation cost of passenger cars on a passenger-per-mile basis. Four years ago 37 per cent of American motor-trucks had four-speed transmissions; today 62.2 per cent have them.

Other changes in design will be brought about by gear-tooth grinding. Transmission shafts will have to be designed so that all the gear-teeth can be reached with a grinding-wheel; cluster gears, made in one piece with the shaft, must go. The car-owner then can buy one gear without buying a whole assemblage of gears.

A few years ago our organization advocated the use of helical timing-gears in place of the spur timing-gears that were then in vogue. The reason was that the helical gears split up the errors in tooth-form and spacing, so that with a given degree of accuracy, helical gears are quieter than spur gears. The process of gear-tooth grinding that we now use has changed conditions so that it is now possible to make spur gears more accurate and it may come about that spur timing-gears with hardened and ground teeth will replace helical timing-gears and chain drives. The change from helical to spur gears can be made very easily, when spur gears are to be

ground, as the grinding process handles an odd diametrical pitch as well as any standard pitch. The diametrical pitch of spur gears will be the diametrical pitch of the helical gears multiplied by the cosine of the helix angle, thus maintaining the same number of teeth to the same center-distance.

THE DISCUSSION

QUESTION:—What time is involved per tooth or per gear?

E. J. LEES:—For taking one cut, or really one cycle, consisting of two passes of one side of the gear-tooth over the wheels, 15-tooth gear, 14.4 sec. per tooth; 17-tooth gear, 13.2 sec.; 18-tooth gear, 10.8 sec.; 21-tooth gear, 9.6 sec.; 25-tooth gear, 9.6 sec.; 29 and 31-tooth gears, 8.4 sec. This is on six to eight-pitch gears with the wheel running at 5000 ft. per min.

QUESTION:—Do you prescribe a wet or a dry grind?

GLENN MUFFLY:—A wet grind always.

QUESTION:—Is there any drawing action on account of heat?

MR. MUFFLY:—Not more so than in any other wet grinding. We grind off ordinarily only about 0.003 in. If there is more to be removed we take two cuts. It is all wet grinding, so one need not worry about taking out the hardness produced by heat-treatment.

QUESTION:—What is the cost per tooth for grinding by this process?

MR. LEES:—You have the time per tooth and you each know what the overhead is in your own plant. Today I was told by a Detroit manufacturer that he had ground 38,850 teeth on both sides, two cuts, four passes, on each side, using a No. 3850-I silicate wheel. This is equivalent to 77,700 teeth ground twice round on one side. A vitrified wheel would show a longer life. A recent change in the form of the wheel will add to these figures. The cost per wheel is about $30.

MR. MUFFLY:—One user gave a figure of $1.75 per transmission. Another said that the cost per transmission was a few cents more than the cost of the finishing cut, which was replaced by grinding, but that he made it up in the saving in the cost of assembling.

QUESTION:—Do the chatter marks from the grinding-wheels show on the testing-machine?

MR. MUFFLY:—No.

QUESTION:—How do you prevent dirt from getting between the tape and the segment?

MR. MUFFLY:—These parts are well protected from the flying particles and the direction of wheel rotation throws the particles off in the opposite direction. We have never had trouble with dirt getting under the tapes; if it should happen we should note the error on the gear-tester.

QUESTION:—Is the durability improved by grinding?

MR. MUFFLY:—Yes; the life of a gear is lengthened by having the tooth-curve correct. Ground gears not only save gasoline but they save wear-and-tear on the gear-teeth, as well as on the ear-drum.

QUESTION:—Is there much trouble with the breaking of the tapes when used with small numbers of teeth with an involute curve?

MR. MUFFLY:—They all have involute curves. The tapes last longer when wrapped round a large segment than when wrapped round a small segment. We use double tapes so that the breaking of a tape is not a serious matter. There is a great difference in tapes. The tapes that we are now using give practically no trouble. For the first two years our machines ran almost exclusively on constant-drive gears and on reverse idlers, so that we had plenty of experience on small diameters and small numbers of teeth. Much of our trouble was avoided by the application of power to the work-spindle instead of to the slide.

QUESTION:—How close must the center-distance be held?

MR. MUFFLY:—Make it ¼ in. if you wish. The center-distance makes no difference whatever with the involute principle, so long as the teeth hit each other and the next tooth comes into contact before the last one lets go. You will only be using a different part of the curve. Most of you at some time have had a pair of gears that were cut for a certain center-distance and have had to spread the center-distance a few thousandths to make the gears run freely. If the gears were supposed to have a 20-deg. pressure-angle and increasing the center-distance made the pressure-angle 20 deg. 13 min., you might have tacked your name on that particular pressure-angle. Variations in the center-distance make no difference except to increase the pressure-angle. But you must have the teeth thick enough to prevent excessive backlash; if you spread the center-distance, see that the shafts are kept parallel. Do not think, as some persons do, that shafts are parallel just because they are the same distance apart at the ends. If you take two sticks and tie them together at the ends with strings of equal length so that the sticks are parallel when in the same plane, you can twist the sticks about until they actually cross each other and still keep them the same distance apart at the ends. You must check a pair of shafts by a surface-plate to see that they are in the same plane, as well as measure to see that they are the same distance apart at the ends.

QUESTION:—Is any modification recommended?

MR. MUFFLY:—Yes, a very small amount, so small that you would call the tooth a perfect involute if it were measured by any of the older methods.

MR. LEES:—The average amount of modification is probably between 0.0002 and 0.0004 in.

QUESTION:—Does this vary with each particular design?

MR. MUFFLY:—Yes. With every pair of gears there is an individual problem as to interference, clearance, tooth distortion, rigidity of shafts and accuracy of bearings. We cannot make one rule that will fit all cases. Having tried out a transmission and tested each gear on the testing-machine, we find the exact modification and chart it, as has been explained. With this information we are able to reproduce the tooth-form absolutely, so that the gears that are cut next week and next year will run quietly with those that are cut today. We actually measure the noise in the tooth-form before the noise occurs.

QUESTION:—What amount of grinding stock should be left on gears of eight diametral pitch?

MR. LEES:—About 0.002 to 0.003 in.

MR. MUFFLY:—If the gears are roughed out accurately and the heat-treatment does not produce much distortion, we can get by with as little finish as 0.002 in. but sometimes we find that the gears are out considerably more than this and we have to take off from 0.003 to 0.005 in. to correct the teeth.

QUESTION:—Is it worthwhile to correct gears other than those of heat-treated steel by the grinding process?

MR. MUFFLY:—Yes; if you are particular about accuracy. Automobile transmission gears present the most urgent problem. To get an accurate spur gear of cast iron or of bronze it should be ground by this process.

QUESTION:—How about the time, the accuracy and the like required for grinding both sides of the tooth?

MR. MUFFLY:—We grind teeth on both sides but not at the same time. It takes twice as long to grind both sides, but it is advisable if you want real accuracy.

QUESTION:—What is the effect of cutting a gear undersize to obtain freedom of motion on the tooth-form?

MR. MUFFLY:—The effect is to give pitch-line clearance or backlash. If the gears are meshed on a lesser center-distance, the effect is to reduce the pressure-angle. We accomplish the desired result by grinding the teeth thinner, not by cutting in deeper with the wheel. A popular misinterpretation of this is seen on many blueprints. A six-pitch gear with 30 teeth has a 5-in. pitch-diameter, but the pitch-diameter is specified on blueprints as 4.998 in. or something like that. The designer means that he wants the teeth to be cut deeper so as to obtain a certain amount of backlash. It is absolutely impossible to generate a six-pitch gear with 30 teeth at any other pitch-diameter than 5 in. You may set the hob in deeper or you may grind the tooth thinner, but the pitch-diameter of the gear is determined by its velocity-ratio relative to the hob or grinding wheel. The moment you remove the gear from the machine it loses its pitch-diameter, and when you mesh it with another gear it acquires a pitch-diameter, but not necessarily the same one as that on which it was cut. The expression "cutting a gear at less than standard pitch-diameter" has been inherited from the old-style disc-type gear-cutter, which really produced a bastard tooth when the cutter was set in deeper.

QUESTION:—Does the irregularity of the rough-cut gear affect the grinding sufficiently to require more time on some gears than on others?

MR. MUFFLY:—Yes; some gears are so badly cut that we have to give them an extra cut on the grinding machine. Ordinarily, 0.003 in. is ample allowance for a grinding-finish. If the roughing machines leave greater errors than this it would pay to replace them with more accurate machines. Gear-grinding is creating a demand for single-purpose heavy-duty hobbing machines to meet this condition. The form of tooth produced by hobbing comes nearer to the true involute than that produced by other methods; consequently there is less metal to be removed by the grinding machine.

QUESTION:—What backlash can be used with ground gears?

MR. MUFFLY:—The maximum variation in the tooth spacing and the tooth contour of gears ground by our process is 0.00025 in. A quarter thousandth of backlash will take care of this provided the rest of the machine-work is accurate enough to allow such a small tolerance. Backlash has heretofore been allowed to accommodate the variations in the gear-teeth, but now you have only to provide the amount of tolerance required to match the tolerance on the center-distance and the eccentricity of the bearings.

QUESTION:—Can bevel gears be ground?

MR. MUFFLY:—There is no machine on the market for that purpose at present.

QUESTION:—Does the process of heat-treating become simpler or cheaper due to truing in the final operation?

MR. MUFFLY:—It becomes both simpler and cheaper. Some manufacturers are going to considerable additional expense in heat-treatment to hold the distortion down to the minimum. This expense can be avoided. Other manufacturers have found it impracticable to use certain steels that possess very good physical properties but do not finish smooth. Steels that may be less expensive than those used in the past can now be adopted, as the grinding machine will put a good finish on them. Some manufacturers use low-carbon steels and go to considerable expense to carburize the gears after roughing them, then finish-cut and quench them from a comparatively low temperature, to minimize the distortion. This expensive carburizing operation can be reduced or eliminated entirely by using different steel and by finish-grinding after heat-treating.

QUESTION:—Have efficiency tests been made to determine the gain made by grinding? If so, how much has the efficiency been increased over that of ordinary gears?

MR. MUFFLY:—I do not know of any extensive tests for that purpose. There is no doubt that grinding makes the gears more efficient. Irregularities that cause noise must also decrease the efficiency. In worm gears the efficiency is increased by the introduction of the tangential feed of the hob, which provides more complete generation. We have seen cases, such as those of turbine drives, in which hardened gears had considerable tooth distortion and were shorter-lived than soft gears of more accurate tooth-form. The efficiency, the quietness and the life of a gear are very closely associated.

QUESTION:—Does not variation in oil-film thickness due to the temperature and the quality of the oil more than offset the close limitation of the variations permitted with tooth-grinding?

MR. MUFFLY:—Yes; I believe this would be true except for the fact that the pressure per unit of area on transmission-gear teeth is so high as practically to eliminate the oil-film on the line of tooth contact. On gears of relatively large diameter, where the machine-work on other parts is very accurate, it would be necessary to make an allowance for the expansion of the metal itself.

QUESTION:—Would you recommend a lighter lubricant in a transmission using ground gears?

MR. MUFFLY:—Not necessarily. If the heavy lubricant were put in solely for the purpose of deadening the noise, then yes; if the heavy lubricant were put in for lubrication, then I should keep it. You know second-hand dealers have a way of taking old cars and filling them up with heavy oil with a little ground cork in the transmission and differential; it makes them run quietly for a little while.

T. J. LITLE, JR.:—That is exactly what I had in mind when I asked that question. I thought you might recommend a lighter lubricant, because it tends to become heavier with use.

MR. MUFFLY:—I should say that ground gears obviate the necessity for a heavy body to deaden the noise and enable this problem to be treated from the standpoint of lubrication only. Of course, there is a sliding action between the teeth, except at the pitch-line, and ground gears do need lubrication, but they do not make so much fuss about running out of lubricant as ordinary gears do, and they do not require a heavy oil to gum the teeth and deaden the vibration. Lighter oils may have as much lubricating value as heavy oils and therefore may be preferred.

QUESTION:—If tooth deflection must be compensated for, how can noise be eliminated under variable loads?

MR. MUFFLY:—You will never eliminate the difference in tooth deflection between a heavy load and a light load, but if you make enough modification to avoid interference under maximum load, you will also avoid interference on light and medium loads. If you take

care of the maximum load, you will be on the safe side.

QUESTION:—If a correction of profile is made to take care of the tooth deflection under load, what effect will it have when the gears are running idle?

MR. MUFFLY:—It will have the effect of giving a little additional clearance at the point of the tooth. If you have a full-depth six-pitch tooth and have made the necessary modification for tooth deflection under full load, then under a light load you will be using practically a stub-tooth gear, as the point of the tooth will not be working at all. You will merely be using a little less of the involute curve, the same as you would use on a stub-tooth gear.

QUESTION:—Referring to timing-gears, not hardened, what objection is there to swaging teeth by rolling them under pressure with a ground master-gear?

MR. MUFFLY:—It would help some by wearing off the high spots, but it would not be equal to a ground gear. This is a burnishing operation that requires a frictional contact on the surface to be burnished. At the pitch-line you have a rolling contact instead of a frictional contact, so the burnishing will not be uniform. The idea of working from a master gear was given a rap by a general foreman with whom I talked recently. He said that a certain inventor of a gear-grinding machine that uses a master gear and rack to get the relative motion was trying to sell the idea to this plant. The foreman asked, "Where did you get the master gears?" It appeared that the master gears were ground on a machine using tapes to get the relative motion. The foreman then asked, "Why not use the tape principle and make all the gears master gears?" The closer you stick to basic principles the better gears you will get. Any shop that has a cylindrical grinding machine can grind a tape segment very close to the desired diameter. Anybody can dress the wheel to a flat surface. It is by sticking to these basic principles that we keep within such narrow limits.

QUESTION:—Does the straight-edge roll on the base-circle without slippage when testing?

MR. MUFFLY:—Yes. If it slips, you will get a jump on the indicator that will look like that produced when testing a gear before grinding.

QUESTION:—Have any experiments been made to apply this method to the grinding of spiral bevel-gears?

MR. MUFFLY:—Yes; experiments, but not in a production machine.

QUESTION:—What do you consider to be the limit of index error on a transmission pinion; that is, the cumulative error?

MR. MUFFLY:—It is the tooth-to-tooth error that is important. If the tooth-to-tooth error is less than 0.00025 in., the gear will be reasonably quiet. It makes no difference whether the error is cumulative round the gear and comes back again to the starting-point, or goes up and down tooth by tooth; the effect is the same; the limit that we set on it is 0.00025 in.

QUESTION:—How do you determine the radius of the tooth-curve due to deflection by considering the variation of load on the tooth and the different elastic-limits of the materials used in gears?

MR. MUFFLY:—We do not calculate that theoretically. We take off an amount that has been found satisfactory in other transmissions and put the gear to the test. If it is quiet we stick to that form; having the testing-machine and the means for plotting the curve, we can hold our production to the desired form.

QUESTION:—What is the actual time required to grind a driving-gear of 1½-in. face, with 18 teeth, and a driven gear with 30 teeth, 7/8-in. face, both six-pitch?

MR. LEES:—For the 18-tooth gear, 3¼ min.; 4 1/4 min. for the 30-tooth gear.

QUESTION:—Do you advocate grinding both sides of the tooth?

MR. MUFFLY:—Yes.

QUESTION:—Which is the more important, the spacing or the profile?

MR. MUFFLY:—They are equally important. We have the same limit on both, 0.00025 in.

QUESTION:—Do the grinding-machines index automatically, or is each tooth indexed by the operator when it is finished?

MR. MUFFLY:—The machines index automatically from tooth to tooth, and are set to stop automatically at the end of one complete revolution; or, in case of grinding twice round the gear, at the end of two complete revolutions.

QUESTION:—What is necessary in tooling-up for a given gear besides making a special segment for the machine?

MR. MUFFLY:—Making an arbor to hold the gear; that is all, unless you have to buy a new index-plate for the number of teeth. An index-plate for a certain number of teeth can be used for all pitches. The wheel is not changed when you change from one pitch to another. The only change required in going from one pressure-angle to another is to swivel the grinding-wheel spindle to whatever pressure-angle is desired.

QUESTION:—With the correct contour and spacing, what effect has the amount of backlash on gear noise?

MR. MUFFLY:—With a constant load it will have no effect. With an intermittent load the effect will depend on the amount of backlash and the amount of variation in the load or the reversal of the load. When the load, not necessarily the direction of rotation, is reversed you will get a click. The volume of noise from this source will depend on the velocity of the load reversal, the amount of torque involved and the amount of backlash. If you are driving in one direction all the time with a constant load, the amount of backlash will make no difference. The teeth can be cut down to one-half their thickness without affecting the noise, except that you would weaken the teeth and so increase the distortion.

GEORGE E. GODDARD:—I think, perhaps, a camshaft load is meant.

MR. MUFFLY:—On a camshaft drive, you would, of course, have an intermittent load, and it would be advisable to hold the backlash down. If you can hold the center-distance accurately enough, you can, with ground gears, keep the backlash down to a point where it will produce no noticeable noise. The amount of backlash to be allowed will depend on how closely you can hold the center-distance. You could vary the center-distance at will, without affecting the involute principle, provided you vary the tooth thickness with the center-distance. If you cannot hold the center-distance accurately enough it will be necessary to grind some gears with thick teeth and some with thin teeth so as to reduce backlash by selective assembling. The only reason for holding the center-distance accurately is to hold down the backlash.

QUESTION:—Have you determined what effect the pressure-angle has on gear noise?

MR. MUFFLY:—We sometimes recommend a small pressure-angle and sometimes a large pressure-angle. If the number of teeth is large, with an intermittent load such as on a camshaft drive, I should advise a small pressure-angle, because with a large number of

teeth you will not have the interference problem, and with a small pressure-angle a given variation in the center-distance will produce less backlash. We may, therefore, say that the small pressure-angle is desirable from the standpoint of quietness, because it makes it easier to hold down the backlash. On the other hand, in automobile transmissions you have a smaller number of teeth, and the tooth load is considerably greater, in which case it is advisable to use a larger pressure-angle to avoid interference and to minimize tooth distortion. A large pressure-angle will avoid the undercutting of the pinions and will give a stronger tooth-form. In a general way, about 20 deg. is good for transmission-gears and about 14½ deg. for timing-gears.

QUESTION:—Do you have trouble with checking when grinding carburized and hardened gears?

MR. MUFFLY:—We have very little trouble, probably because our grinding-wheel generates the curve and so is not in contact with the entire side of the tooth at one time. I should say that the problems of gear-tooth grinding are the same as those of cylindrical grinding, so far as steels, coolant, heat-treatment, wheel material, loading and burning are concerned.

QUESTION:—Is checking more prevalent with some types of steel than with others?

MR. MUFFLY:—I believe it is.

QUESTION:—Please discuss the effect of modification as shown by your diagrams.

MR. MUFFLY:—Referring to Fig. 5, let us consider first the teeth on the driving gear. They will be deflected backward while under load. We can correct this by adding to the driving sides of the teeth near the point and by taking something off the rear sides of the driving teeth near the point. In other words, we give the teeth a little slant forward so that when deflected they will come back to the true involute. This can be accomplished by tilting the grinding-wheel to a slightly smaller pressure-angle when grinding the forward sides of the driving teeth, and to a slightly greater pressure-angle when grinding the rear sides of the driving teeth. In automobile transmissions, the driving gear is almost always smaller than the driven gear; and there will be a greater tooth-deflection with a small number of teeth than with a large number of teeth, because of the difference in tooth-form between the large and the small number of teeth. Consequently, more modification will be necessary on the driving gear than on the driven gear. Assuming that the tooth a_2 on the driving gear has been modified in this manner and being under load has been deflected back to its true position, the driven tooth b_2 will be deflected forward slightly, causing the tooth b_1 to lag slightly; also, the tooth a_1 on the driving gear is ground full on its leading side and, since it is not yet under load, we shall find that the teeth a_1 and b_1 engage before they should. For this reason, we slightly relieve the points of the teeth on the driven gear. This is a theory that will explain the reasons for the modifications that we have found effective in practice, rather than a rule to be applied universally to gears.

QUESTION:—How do you calculate the diameter of the base-circle for grinding the involute curve?

MR. MUFFLY:—In the first place, it is the pitch-circle that we use on the grinding machine, not the base-circle. I will, however, explain the method of calculating the base-circle diameter. Referring to Fig. 3, which shows the relation of the base-circle to the pitch-circle, you will recall that the line $b\,c$ was drawn perpendicularly to the line $a\,b$ and therefore $a\,b\,c$ is a right-angle triangle, of which we know the length of side $a\,c$, the pitch radius, and the angle $b\,c\,a$, which is equal to the pressure-angle. What we want to know is the length of the line $b\,c$, which is the base-circle radius. The rule is, to multiply the pitch radius by the cosine of the pressure-angle to get the base-circle radius; in other words, the pitch-diameter times the cosine of the pressure-angle equals the base-circle diameter.

QUESTION:—How about the effect of pitch overlap on noise?

MR. MUFFLY:—Meaning, I assume, the number of teeth in contact. The more teeth there are in contact the more there will be to share the load and to divide the deflection. As a rule the problem is easier with a large number of teeth than with a small number. We grind pinions successfully down to the smallest numbers of teeth used in automobile transmissions. It is easier to make a 30-tooth gear run quietly than it is to make a 12-tooth pinion run quietly, not only because more teeth are in contact and thus divide up the deflection, but because a larger number of teeth makes it easier to keep clear of interference.

W. R. GRISWOLD:—That is the reason for getting into odd pressure-angles?

MR. MUFFLY:—Yes; odd pressure-angles frequently are employed when it is found that the standard pressure-angle produces interference; the pressure-angle is increased just enough to avoid the interference. Odd pressure-angles can be handled with no change except tilting the grinding-wheel to a different angle. When you have a train of gears designed to be cut at different pressure-angles and to run together at some common pressure-angle between each pair, you can grind the entire train at one setting of the wheel by making the necessary changes in the segment diameters. You can grind a gear with a number of different settings and have the settings all come out alike; each change of the tape-segment diameter will bring you to some particular pressure-angle on the involute curve, and the grinding-wheel then will be set at this pressure-angle. All the gears will have the same base-circle and will employ the same circle on the gear-testing machine.

QUESTION:—What is the authority for computing the base-circle according to the rule Mr. Muffly stated?

MR. MUFFLY:—When you know the length of the hypothenuse and the angle opposite the perpendicular, you multiply the hypothenuse by the cosine of the angle to get the length of the base-line. This is a mathematical law, not a rule that I have invented. Taking this triangle, shown in Fig. 4, fitting it into the triangle $a\,b\,c$ in Fig. 5 and applying a little plane geometry, we prove that the angle $b\,c\,a$ is the same as the pressure-angle; the angle $t\,a\,b$ plus the angle $b\,a\,c$ equals one right angle, because the tangent $t\,t$ was drawn at right angles to the radius $a\,c$; the angle $b\,c\,a$ plus the angle $b\,a\,c$ is also known to equal one right-angle, since $a\,b\,c$ is a right-angle triangle; therefore, we know that the angle $t\,a\,b$ equals the angle $b\,c\,a$, thus proving that the angle $b\,c\,a$ is the same as the pressure-angle, because the angle $t\,a\,b$ is the pressure angle.

QUESTION:—Will ground non-metallic gears running with ground metallic gears give additional quietness?

MR. MUFFLY:—We have not ground any non-metallic gears. It seems that non-metallic material is unnecessary in a ground gear. It has been suggested that a hardened and ground spur-ring gear be made with a non-metallic hub; this might be worth experimenting with on a camshaft drive to deaden the vibration produced by the intermittent load.

QUESTION:—What effect does grinding have on the tone of the gear noise?

MR. MUFFLY:—We have quit specifying gear-teeth according to the tone of the noise, for it is impossible for any man to grade gears accurately by this method. We used to be able to identify different makes of car by the different tones of gear noise. The Panhard and the Mercedes had distinctive tones.

Methods of gear testing have changed. We no longer roll the gears together by hand, make optical inspections of tooth engagement or judge tooth errors by the tone of the gear noise. What we want is no noise at all, or gears that run so silently that there is not enough noise to analyze.

A demonstrator recently reported that the engineer at a certain factory had asked him to grind a set of gears on exact involute curves. When the gears were projected on the screen, the engineer said, "If those gears are not quiet, then no one can produce a quiet gear." The demonstrator maintained that they would not be quiet, and they were not. He then ground gears with slightly modified teeth, as described earlier in this discussion; they were quiet. The answer is, you want correct involute curves while the gears are under load rather than while they are on the testing machine.

The high or low-pitch sound that we had before the time of grinding disappears almost completely. The magnitude of the sound is very much decreased. Certainly the sound is more pleasant to the ear.

QUESTION:—Would not a 0.002-in. cumulative error between the first tooth and half-way round the gear give an "eccentric" sound?

MR. MUFFLY:—No; because that condition would not make the gear eccentric. An "eccentric" sound comes from the teeth meshing tightly on one side and loosely on the other side. In this case there would be a slight amount of acceleration and deceleration, but not that eccentric sound, nor the sound produced by a large tooth-to-tooth variation; there would be very little difference between the sound made by a gradual increase of 0.0001 in. per tooth and that made by a gradual decrease of 0.0001 in. per tooth. You would not have any decided click or eccentric sound if the error were uniformly distributed.

QUESTION:—Does the dressing of the grinding-wheel depend on the operator?

MR. MUFFLY:—The frequency, but not the accuracy, of the dressing lies with the operator. The wheel is not dressed during a grinding operation. One dressing is good for from one to six gears, depending on the size of the gears, the amount of metal to be removed and the material. The wheel is fed to the diamond, not the diamond to the wheel; so the dressing does not change the location of the grinding surface.

QUESTION:—Will ground front-end gears be as quiet as the best silent-chains under similar conditions of operation?

MR. MUFFLY:—They ought to be more quiet.

QUESTION:—Could the tape method of grinding be applied to cams instead of following the master cam?

MR. MUFFLY:—That could be done, but we are not grinding cams. On second thought we *are* grinding cams, for every gear-tooth is a cam, a cam that must stand up under heavy service. There are such things as involute cams but not in the valve mechanism of an automobile engine. If you use the tape method of grinding on something else than an involute cam you would wrap the tape about some other form than a circle.

QUESTION:—How could you obtain a constant velocity between a rack and the pitch-circle of a gear by a base-circle of less than the pitch-circle of the gear?

MR. MUFFLY:—The base-circle is always less than the pitch-circle. The base-circle velocity must be the same on any two mating gears and the pitch-circle velocity of the two gears must, of course, be the same. The ratio between the base-circle velocity and the pitch-circle velocity is represented by the cosine of the pressure-angle. In a rack we have only the pitch-line to consider, and the rack movement is always equal to the pitch-circle movement. On the grinding machine we get the relative movement of the rack tooth from the pitch-circle, not from the base-circle. On the testing machine we get the movement of the indicator-point by rolling a straight-edge on the base-circle. The base-circle of a gear must be smaller than the pitch-circle; otherwise there would be no pressure-angle at all.

QUESTION:—If the involute teeth slide on each other, would not the wear, in time, produce a flat straight line on the pitch-circle, and the wear of the forward flank cause noise?

MR. MUFFLY:—Involute gear-teeth do slide on one another and the frictional contact does cause wear. The wear is not concentrated on the pitch-line, however. On the contrary, we have a rolling contact at the pitch-line and the amount of the sliding motion increases each way from the pitch-line. The more nearly perfect the involute curves are, the better the finish on the teeth will be; and the harder the working surface is, the less the teeth will wear. Gears with correct tooth-curves will wear more uniformly than gears with incorrect teeth. The process of gear-tooth grinding now in use produces the most correct tooth-curves yet obtained in gear production, and consequently the gears are quieter and will stay quiet longer, because the wear is uniform.

PRACTICAL RESEARCH

WHEN one thinks of a laboratory, the natural conception is of a place where theorists work on purely scientific problems. The patience of the scientific investigator has won him many laurels, but has not gained him the support of the man in the shop who depends on the skill and speed of his hands and rule-of-thumb methods to meet any demands for increased production that may arise. Rule-of-thumb methods of manufacturing are still adhered to in many plants. There has been a decided awakening, however, on the part of the majority of American business men.

What is considered the science of yesterday is available for the business man of today, if he will but use it. One of the best ways to do this is to establish a works laboratory and place it in charge of a scientifically trained man. Briefly stated, the function of such a works laboratory is to apply scientific principles to the manufacture of the firm's product, so as to raise the standard of quality and still keep the cost at a minimum.

If placed in charge of the proper man, the laboratory should be the best paying department of a business. We have not yet attained 100-per cent efficiency in any mechanical process and we probably never will. The aim is to eliminate as much of the existing waste as possible.—A. L. Collins in *Machinery*.

THE SOCIETY'S STANDARDIZATION PROCEDURE

IT is the function of the Society's Standards Committee to formulate, if feasible, standards and recommended practices that will simplify and coordinate routine and engineering practice on all subjects assigned to it by the Council. To facilitate the work, the Standards Committee is resolved into 27 Divisions, each being representative of a particular branch of the industry.

Personnel

The Standards Committee is presided over by a chairman and two vice-chairmen. Each Division has a chairman and one vice-chairman. The Standards Committee and Division chairmen are designated by the President of the Society, the other personnel of the various Divisions being appointed by the Council. In addition to the Division personnel, Subdivisions are appointed to formulate tentative reports covering important subjects that are under consideration, the Subdivision members being appointed by the Division chairmen. The Subdivision chairmen are usually members of the Divisions to which the Subdivisions report, but other Subdivision members are selected from the industries at large to assure the assistance of the best-qualified men in each particular field.

Members of the Standards Committee need not be necessarily members of the Society, such committee members being known as conferees and having all the privileges of regular committee members except that of voting. In selecting members of the Standards Committee importance is placed on obtaining men of broad experience and so far as possible familiarity with standards work. Many of them naturally are associated with the older and better-known companies, but they are selected for their personal qualifications.

Initiation and Procedure

The assignment of subjects to the various Divisions is generally based on requests that have been received from members of the Society or the industry directly affected. Subjects are not assigned by the Council unless their standardization is considered feasible as well as desirable. Upon assignment to the proper Divisions, the various matters are studied with relation to the limiting phases within which standardization can be accomplished and the probable requirements of the industry affected. If a subject is involved, the features that the standard should embody are outlined and an approval of the outline obtained from the companies interested. The industries are then circularized for data representing current practice and suggestions for consideration by the Division members. The information is then, as a rule, referred to a Subdivision for the formulation of a tentative proposal which, when submitted, is referred to the industries for comment. The tentative proposals, together with the comments received, are then referred to the Divisions, and revised to meet all valid objections which may have been made. The Division recommendations are then printed in The Journal prior to consideration of them at the next meeting of the Standards Committee.

Division reports may be approved only by the Standards Committee at regular meetings held semi-annually or at special meetings called by direction of the Council. These meetings are open to Society members and non-members alike. The reports are discussed and may be approved as submitted or in revised form or referred back to the respective Divisions for further consideration. After Standards Committee approval the reports go to the Council and if approved are acted upon at a regular business meeting of the Society. The reports may be amended at these meetings but are usually approved as submitted. The reports are then submitted to the voting members of the Society for adoption by letter ballot, a majority of the votes cast being necessary to make the recommendations official S.A.E. Standard or Recommended Practices. The results of the letter ballot are referred to the Council, and in case a recommendation encounters several negative votes supported by sound engineering reasons, the Council may withhold its publication in the S.A.E. Handbook until the reasons submitted shall have been reviewed by the Division making the recommendation.

Although the regulations provide that a majority of votes shall be necessary to approve a recommendation, a recommendation is seldom approved unless the action is practically unanimous. The reasons for this are patent, as well-founded objections to any adopted recommendation would militate against its general reduction to practice, resulting in a "paper standard" only.

The time required for the stated procedure varies from 3 months to in some cases a number of years, depending upon the conditions involved. A large amount of office work is required in corresponding with the industries and members of the Divisions, arranging meetings and keeping progress records.

S.A.E. Handbook

Subsequent to the Standards Committee meeting, the revisions of the reports together with the discussions thereon are printed in the following issue of The Journal, the revised reports as approved being printed in the next issue of S.A.E. Handbook data sheets. It is essential that all standards be published in a clear, concise and uniform manner. This was recognized in the beginning by the pioneer members of the Society and its Standards Committee, and the present well-known loose-leaf S.A.E. Handbook has proved the wisdom of selecting this form of publication. Clear detailed drawings with tables and notes are used to set forth the standards and recommended practices. A complete set of the standards goes to all the members of the Society, including the new and revised standards issued twice a year. The complete Handbook is available to non-members of the Society and a single copy of any standard may be obtained upon request to the Society. The standards are not copyrighted, but it is expected that the Society will be given due credit for any of its data reprinted in other publications.

The procedure of revising existing standards is the same as when the subjects are originally considered. As such revisions are not published in the S.A.E. Handbook until they have been approved by letter ballot of the voting members and this procedure usually takes several months, it is well for all interested to ascertain whether a standard is under revision in case production on a design involving the use of a S. A. E. Standard is contemplated. Complete information in reference to the current work of the Standards Committee is published regularly in The Journal.

CURRENT WORK OF THE STANDARDS COMMITTEE

AUTOMOTIVE DIVISIONS

AERONAUTIC

No active subjects

AGRICULTURAL POWER EQUIPMENT

Plowing Speeds
Tractor Rating
Tractor Testing Forms

ELECTRIC VEHICLE

Lamp Bulbs for Electric Vehicles
Storage Battery Tray Terminals

ISOLATED ELECTRIC LIGHTING PLANT

No subjects assigned

MOTORBOAT

Control Levers
Engine Couplings
Engine Testing Forms
Stuffing Boxes
Tachometer Drives
Trial Performance Forms

MOTORCYCLE

No subjects assigned

PASSENGER-CAR

Brake Tests
Frame Numbers

STATIONARY-ENGINE

No subjects assigned

TRUCK

Power Take-Off Shaft-Ends

PARTS AND FITTINGS DIVISIONS

AXLE AND WHEELS

Brake-Drums
Differential Gears
Solid-Tire Felloes
Wire-Wheel Spokes

BALL AND ROLLER BEARINGS

Corner Radii
Inch-Type Roller-Bearings
Medium-Heavy Ball-Bearings
Wide-Type Ball-Bearings

CHAIN

Roller Chains

ELECTRICAL EQUIPMENT

Automobile Wiring

ENGINE

Engine Numbers
Flywheel Housings
Poppet Valves
Starting-Cranks

FRAMES

Motor-Truck Frames

IRON AND STEEL

Part III, Chemical Compositions
Part IX, Heat-Treatments
Sheet Steel

LIGHTING

Bases, Sockets and Connectors
Focusing Mechanisms
Lamp Glasses
Motorboat Lighting Equipment

LUBRICANTS

Crankcase Lubricating Oils
Transmission Lubricants

NOMENCLATURE DIVISION

No subjects assigned

NON-FERROUS METALS

Wrought Non-Ferrous Alloys

PARTS AND FITTINGS

Flexible Discs
License-Plates and Brackets
Wire Mesh

PASSENGER-CAR BODY

Aluminum Molding
Aluminum Sheet
Body Nomenclature
Brass Molding
Door Hinges
Hardwood Lumber
Paints, Varnishes and Enamels
Steel Molding
Strap Loops
Upholstery Leather

RADIATOR

No subjects assigned

SCREW-THREADS

Screw-Thread Practice
Tire Valves

SPRINGS

Definitions
Leaf-Spring Nomenclature
Motor-Truck Springs
Passenger-Car Springs
Spring Specifications
Tests for Parallelism of Spring-Eyes

STORAGE BATTERY

No subjects assigned

TRANSMISSION

Clutch Housings
Transmission Tire-Pump Mounting

New Principles in Rotative Balance

By Amos F. Moyer[1]

Minneapolis Section Paper *Illustrated with* Photograph

FOLLOWING the presentation of this paper, written discussion was submitted to which the author was given an opportunity to reply. The discussion and the reply are printed herewith, with the understanding that the duty of THE JOURNAL has now been performed and that this discussion is thereby closed. For the convenience of the members, an abstract of the paper is presented also, together with a reference to the text and illustrations already published.

ABSTRACT

WITH the advent of high-speed machinery, the ordinary methods of rotative balancing were found insufficient. Rotative bodies that had been given the most careful static or standing balance would vibrate seriously when running, because of an unbalanced couple consisting of two quantities of equal magnitude on opposite sides of, but displaced from each other along, the axis. Thus, a second consideration in rotative balance, called dynamic or running balance, was introduced.

Until the invention of the balancing machine that the author describes, there were no means for measuring directly the resultants for the two separate ends of a rotative body, but now these quantities can be measured directly and located without the necessity of separating the standing from the running balance. The new principles are demonstrated mathematically with the aid of diagrams, the balancing machine is illustrated and described, and comments are made to afford a correct conception of the subject of balance. [Printed in the October, 1922, issue of THE JOURNAL.]

THE DISCUSSION

F. Hymans[2]:—With reference to the paper entitled New Principles in Rotative Balance, wherein A. F. Moyer describes a balancing machine invented by Dr. B. L. Newkirk, the object is to inquire into the processes employed in that machine and to refer to their novelty, for which extravagant claims are made. According to the paper, the novelties are (*a*) an alleged new principle, by inference the discovery of Dr. B. L. Newkirk, that one, and only one, correction is required in each of two arbitrary planes of revolution to eliminate the lack of balance in a body; and (*b*) a machine employing this principle and wherein no distinction is made between standing and running balance.

As to the novelty of the principle, I quote from the English translation of Stodola[3]: "Complete mass-balance can be obtained in the case of rotation about a fixed axis by the addition of two suitable masses in two otherwise arbitrary planes at right angles to this axis." Stodola is surely no obscure authority and, as his book appeared 17 years ago, the claim as to the novelty of the principle cannot very well be maintained.

Regarding the second point, Fig. 10 is a photograph of a turbine rotor in the process of balancing on one of the Akimoff heavy-duty balancing machines, which is made in capacities up to 150,000 lb. This type of machine employs the principle announced as new by Mr. Moyer. It does not distinguish between static and dynamic balance, and only two corrections are made each in a plane at right angles to the shaft. In the older types, the body had to be reversed exactly as in the Newkirk machine. In the later types, two vibrating supports are provided one of which is locked at a time. The Akimoff machine has found a wide distribution in this country and has been on the market since 1917. Thus there is in the Newkirk machine neither a new principle nor is he the first to apply it.

The paper describes a method for locating the axial plane of the required corrections on the body. Mr. Moyer does not say that the results of this method are only approximate. It requires the measuring of two amplitudes, and it is pointed out below that very slight errors in the observations lead to gross errors in the desired location of the axial plane of correction.

Many years ago Norton devised the so-called high-spot method, the results of which are more accurate than the Newkirk method. The high-spot method has the advantage that no observations or calculations on a slide-rule have to be made by the operator. Besides, the result of Newkirk's observations and calculations is an angle; namely, the angle locating the axial plane of correction with reference to an eccentric weight. But it does not inform the operator whether this angle should be laid off to the right or to the left of the eccentric weight, and another trial run is required to decide this question.

Newkirk does not lay off the plane of corrections on the work in accordance with the result of his calculations as he might do if the method really were one of precision. No, he provides the means to test them; he adjusts and readjusts these means until by experimentation, and by nothing else, he locates the plane of correction. These means help him to determine another element, which his previous calculations do not give; namely, the *amount* of the required correction. The means referred to are a weight the angular and radial positions of which, with reference to the work, can be adjusted at will. The first to employ it in an organized manner on balancing machines is N. W. Akimoff.

Furthermore, the Newkirk balancing machine is arranged so that the oscillations of the work are of one degree of freedom, which again is copied from Mr. Akimoff. The Newkirk machine requires that the body in its original and reversed positions be placed on the machine so that the two planes in which corrections are to be made comprise in each test the axis around which the body oscillates. This is the only point in which it differs from the heavy-duty Akimoff machine; it facilitates slightly the required calculations. On the other hand, this feature severely restricts the field of application of the Newkirk machine. It is limited to bodies approximately the same end-for-end, and the cradle-like construction makes it unsuitable for long and heavy bodies.

Comparing the machines that distinguish between static and dynamic balance, also the invention of Mr. Akimoff, with the Newkirk machine, let us consider the

[1] M.S.A.E.—Chief engineer, Precision Balancing Machine Co., Minneapolis, and consulting research engineer.
[2] Vibration Specialty Co., Philadelphia.
[3] See Steam Turbines, Stodola, p. 174.

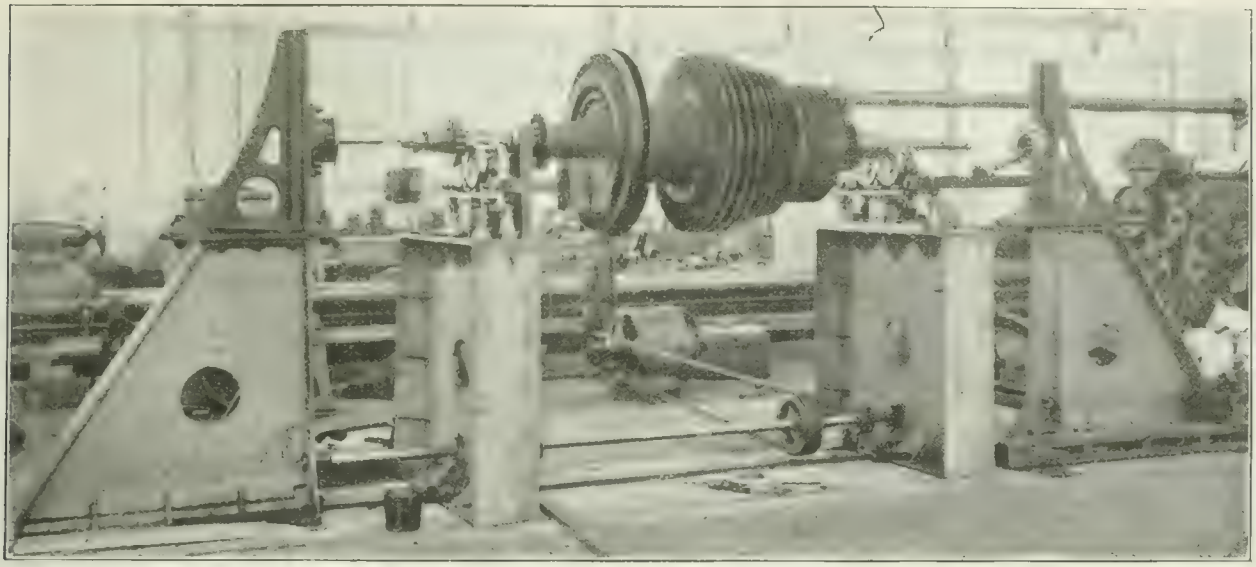


FIG. 10 BALANCING A TURBINE ROTOR

balancing of crankshafts. In the Newkirk machine we must select the webs, and set-up the machine accordingly, at which corrections are to be made *before* we know the state of unbalance of the body. Further, for production, the machine must be set-up once and for all and corrections must therefore *always* be made at the *same* webs, *no matter whether the particular state of unbalance in a given case makes these webs the most suitable.* It is this inflexibility that is the disadvantage of the Newkirk machine. It can, for example, so happen that the state of unbalance is such that the required correction lies outside of the metal of the particular web to which it should be applied; or, it can happen that the required correction is so large that if applied to the web it would weaken it seriously. The machines that distinguish between static and dynamic balance are free from this inflexibility. The states of static and dynamic balance are ascertained *first*, leaving the operator free to correct for each kind of unbalance *at any webs that are most suitable for the purpose.*

Under the heading Misconceptions of Balance, Mr. Moyer comes to the conclusion that a body balanced at any one speed is balanced at all speeds. This, of course, is a cardinal truth, and is very handy to justify balancing at a speed that is most convenient for the particular type of machine. For the approximate location of the axial plane of the required correction, Newkirk reads the amplitude of oscillations with the body alone, and then of the body in combination with an eccentric weight. From the ratio of these amplitudes, the angle locating the required plane with reference to the axial plane of the eccentric weight, whether to the right or left of it only another experiment will tell, is determined. Suppose the first reading is 20 and the second 38; then, the ratio is 1.9 and, on the chart, Fig. 6 of the paper, the corresponding angle is 140 deg., very nearly. If, however, the second reading had been 40, the ratio would have been 2 and the angle 180 deg. Thus an error in the second readings of 2 in 40, or 5 per cent, makes a difference of not less than 40 deg. in the location of the desired plane of correction; and, if there is to be in this method the faintest resemblance of precision, the amplitudes must be read with a very high degree of accuracy. No doubt a slow speed of about 100 to 110 r.p.m., such as Mr. Moyer recommends, is more suited to this purpose than a high speed.

The speed at which the work is to be balanced should not be subordinated to the convenience of a method or of a machine. In a balancing machine, we locate and measure centrifugal forces and nothing else. The larger these are, the more completely and accurately can we measure them and eliminate them. Therefore, the speed at which a body is to be balanced should be comparatively high, materially higher than 100 or 110 r.p.m. for a crankshaft. Balancing at double this speed costs no more, and there is no reason to be satisfied with a residue of 0.2 oz-in. static, or its equivalent in dynamic unbalance when, with the same labor and expense, we can come still nearer to the ideal. Of course, the centrifugal forces are proportional to the square of the velocity of rotation and the light, cheap structure of the Newkirk machine, consisting of rods or tubes clamped together, would not have the required rigidity for balancing at high speed.

A. F. MOYER:—In reply to the comments of Mr. Hymans, I must affirm that there is no statement in my papers which cannot be substantiated and, therefore, nothing to retract. Idle dispute avails nothing and, unless constructive criticism can be offered, there would seem to be little need for discussion. The particular advantages of the Newkirk system lie in precise determinations systematically laid off and applied on the work, both quantity and position being determined by measurement without experimentation or involved calculation. These results are consistently maintained in production in a routine manner successfully carried out by a good average workman. The degree of accuracy obtained by this machine is as fine as commercial applications can feasibly be made, and the rapidity of measurement is far greater than possible by any means of experimentation, including both quantity and angular position.

In comparing angular determinations, the shortcomings of the so-called high-spot method are too old and too well-known to need repetition here, but they include, besides lesser evils, an entire absence of quantity indications and the possibility of entirely false indications, causing wrong applications to be made at one end. Actually, the error in angle claimed by Mr. Hymans is never retained, because a redetermination is effected by an observation at the last position, which results in high accuracy, since the true angle is then small and an error in reading has only a much diminished effect. Whether

the angle is to the right or to the left is determined quickly by trial and, in many classes of manufacture, the process of production will enable the operator to turn the angle in the proper direction the first time on 90 per cent of his measurements.

In the balancing of crankshafts, the objections offered are of no consequence because one can make applications on other webs of the shaft, and the allowances for doing so are no more complicated than the so-called free manner of correction for each kind of balance, an unnecessary distinction that must always be employed with the static-dynamic type of machine. The particular advantages of the Newkirk system, in most directly laying off and applying the corrections on the work can, with proper allowances, be retained and fully realized. It is possible to insure that all corrections will fall within the webs at which they can be applied most easily and systematically, and will never weaken the member. Never more than four points of correction will be required and, by the cut meter, all quantities will be predetermined without special calculation or experiment. On certain types of crankshaft, two points of correction will always suffice. It is better to show an operator what to do than to depend upon his intelligent use of liberty, which must be accompanied by advanced judgment or even mathematical skill.

The detailed design and construction of this precision machine provides a considerable adjustment for unequal end-for-end dimensions and, as I have shown, only one of the planes of measurement needs necessarily to be placed over the pivots; this permits one end of the work to be of any desired excess length, so long as it will go into the machine at all. The lightness of construction employed is far from cheap, and is based upon sufficient reasons to meet the approval of authoritative designers and builders of machine tools, a leading firm of which has taken over the manufacture. As to the charges of copying, imitation and the like, I reply that Mr. Hymans is mistaken as to the identity of the persons first to use the features prominently referred to.

EXPORTS

DESPITE the enormous volume of American manufactures, except in special lines, this Country is not foremost as an exporter of industrial products. Great Britain is still first in export trade in manufactures. Outwardly, the conditions surrounding the development of industry in the United States do not appear to differ greatly from the influences that have conditioned the development of manufactures in Europe. Fundamental differences nevertheless exist. Evidence of them is found in the fact that, in the main, American manufacturers produce for domestic demand, while European industries are heavily dependent on export business.

Despite the enormous production of iron and steel the United States exports only about 6 per cent of the total product, machinery excluded. Before the war Germany exported about one-third of all the iron and steel produced in the country, and in 1922 about 30 per cent. Prior to 1914 the United Kingdom ordinarily exported about half of the product of its blast furnaces and steel mills, and last year it exported 58 per cent. The United States exports between 5 and 10 per cent of all cotton goods made here. The mills of the United Kingdom prior to 1914 exported about four-fifths of their entire product. Exports of woolen and worsted textiles from the United States are negligble. British exports on a pre-war basis were about 40 per cent of the total output. Only about 2 per cent of the boots and shoes made in the United States was exported in 1922; and, out of a total production of 2,577,000 automobiles and motor trucks, exports were but 79,000 or 3 per cent.

The statement has been made that the foreign trade of Great Britain in pre-war days was calculated at about 25 per cent of its domestic trade. The export market is probably somewhat less important to Germany, but the profitable operation of German industry nevertheless depends upon it; and the same is true of the industries of the Netherlands, of Italy in so far as Italy is an industrialized country; of the major industries of France, and of the industrialized areas of Austria and the Succession States. The industries of Belgium are of the extreme export type. It has been estimated that in normal times the Belgium glass industry must export 95 per cent of its output; the bottle, goblet and cut glass industries 70 per cent; the zinc industry 80 per cent; the steel industry 66 per cent; the flax-spinning industry 80 per cent; and the match industry 64 per cent.

This difference in the relative importance of export trade to the manufacturing industries of the United States and of Europe has existed almost from the beginning of the development of the factory system in its present sense. In Europe modern industry was superimposed upon countries already fairly mature. Fields had long been tilled. Coal was new as a source of power, but metal mines had been exploited for hundreds of years. In England and in many parts of the Continent, supplies of timber were becoming insufficient for the needs of the people. After the introduction of power spinning and weaving machinery, the use of coal as fuel, with the consequent growth of modern smelting methods and the development of numberless mechanical devices to do the work that had theretofore been done by human hands, it was possible for a time for the European countries to depend primarily upon their own natural resources and their own markets, but this condition did not long prevail. Another circumstance of considerable importance in its effect both on the consuming power of the European market and on methods of production is that before the coming of modern industry, centuries had already stabilized social customs, stratified society and fixed the habits of life of the people.

The manufacturing industries of the United States have developed with the Country. At the same period when the United States, along with Europe, was making its transition from the household and handicraft stages of industry it was also making its transition from the pioneer stage of settlement to an established community. The change was complete. Material, political and social surroundings altered coincidentally with the growth of manufactures. The minds of the people turned away from Europe and toward the West.

Important factors in the sale of American machinery abroad are developments of the principle of interchangeable parts and of the American service systems. These methods are the direct outgrowth of conditions in the United States. Large-scale production tends inevitably to standardization and ultimately to a high degree of interchangeability.—E. M. Miller, National Bank of Commerce.

Reports of Divisions to Standards Committee

THE following 13 Division reports of the automotive and parts and materials divisions of the Standards Committee will be presented for approval at the Standards Committee Meeting on Tuesday, June 19, at 11 a.m. in the Ball Room of the Essex and Sussex, at Spring Lake, N. J., this being the first day of the Summer meeting of the Society.

The reports are printed in this issue of THE JOURNAL to allow sufficient time for Society members and others to study the reports and prepare comments and suggestions for consideration at the meeting which will, as usual, be in the nature of a public hearing. Although only members of the Standards Committee may vote on the adoption of the reports, discussion is invited from everyone, whether connected with the engineering, production or servicing branches of the industry, interested in the adoption in practice of the standards proposed. The recommendations of the Divisions do not necessarily apply to present practice, although they are based to a large extent on present practice. They are intended to be followed by the various industries to which they are applicable when changes in design or production make it economically possible to do so. The general adoption in practice of a given recommendation may be a matter of months or years, depending upon the conditions involved.

A list of the several subjects before the Standards Committee is given on p. 561 of this issue. The detailed procedure followed by the Standards Committee is outlined on p. 560.

AGRICULTURAL POWER EQUIPMENT DIVISION REPORT

Division Personnel

C. B. Rose, *Chairman*	Moline Plow Co.
A. W. Scarratt, *Vice-Chairman*	Minneapolis Steel & Machinery Co.
J. B. Bartholomew	Avery Co.
C. E. Frudden	Hart-Parr Co.
A. H. Gilbert	Rock Island Plow Co.
R. O. Hendrickson	J. I. Case Plow Works Co.
P. E. Holt	Holt Mfg. Co.
John Mainland	Advance-Rumely Co.
M. B. Morgan	Timken-Detroit Axle Co.
J. F. M. Patitz	Allis-Chalmers Mfg. Co.
O. W. Sjogren	University of Nebraska
L. W. Witry	Waterloo Gasoline Engine Co.
G. A. Young	Purdue University
O. W. Young	Hyatt Roller Bearing Co.
O. B. Zimmerman	International Harvester Co.

TRACTOR BELTS AND PULLEYS

Proposed S. A. E. Recommended Practice

During the last year the Agricultural Power Equipment Division, through a Subdivision of which O. B. Zimmerman of the International Harvester Co. is chairman, has been working on the standardization of tractor driving-belts, which had been urged by both manufacturers and users. The specifications originally proposed by the Subdivision have been extensively revised as a result of several meetings at which manufacturers of canvas and rubber belting were represented. The specifications finally developed meet with the general approval of the belting manufacturers as well as the tractor builders. Although some five-ply belts are used in greater widths than specified in the report, it is recognized that to be of the most value the specifications should specify only those sizes most extensively used and absolutely necessary for proper operation under different conditions of various equipments.

Therefore the Agricultural Power Equipment Division recommends for adoption as S. A. E. Recommended Practice the accompanying specifications for tractor driving-belts.

L. W. Arny, secretary of the Leather Belting Exchange, who attended the Subdivision and Division meetings at which this subject was considered, has been appointed a member of the Subdivision to assist in preparing similar specifications for tractor leather driving-belts.

SPECIFICATIONS FOR TRACTOR ENDLESS DRIVING-BELTS

For farm tractors, new endless belts of either canvas or rubber shall measure the full taped and specified length without allowance being made for the splice. This length shall be the single stock-length and correct to within tolerances of plus or minus 0.25 per cent to take care of reasonable shrinkage or stretching in manufacture and changes due to atmospheric conditions.

All belts shall be marked to indicate the pulley side and the preferred direction of running.

TABLE 1—DIMENSIONS AND RATINGS OF CANVAS AND RUBBER BELTS

Belt Width, In.	Number of Plies	Belt Length, Ft. ± 0.25 Per Cent	Approximate Horsepower Rating[1]
5	4	75	18
6	4	50, 75, 100	22
7	4	100, 125	26
8	4	125, 150	30
8	5	125, 150	37
9	5	160	42

[1]The approximate horsepower rating is based on a belt speed of 3000 ft. per min. Belts should be operated in service at one of the S. A. E. Standard belt-speeds.

The 150 and the 160-ft. belts 8 and 9 in. wide respectively are necessary for steam tractors to conform to fire prevention laws in some States and in Canada.

PULLEY DIAMETERS

The driven pulley diameters shall be not less than 7 in. for four-ply and 10 in. for five-ply belts and should be preferably as large as practical conditions permit. To insure good traction and long life, thinner and wider belts should be chosen in preference to thicker and narrower belts.

CANVAS BELTING

Canvas belts shall be made of long fiber belt-duck free from defects and shall weigh not less than 32 oz. per linear yd. 36 in. wide, or an equivalent weight for different widths, when corrected to a basis of 6-per cent moisture.

Belts shall be well stitched with the stitching spaced not more than 9/32 in. apart across the belt and the edges and laps double-stitched with sewing twine of a quality equal to the long-fiber belt-duck.

Canvas belts shall be thoroughly water-proofed by gum, oil or paint that will not injure the fabric and will maintain the belts in a pliable condition so as to furnish good traction throughout normal changes due to wear, temperature and moisture.

RUBBER BELTING

Rubber belts shall contain long-fiber belt-duck free from defects and shall weigh not less than 32 oz. per linear yd. 42 in. wide when corrected to a basis of 6-per cent moisture.

In folding the canvas, the seaming strip shall be not more than one-third of the belt width from the edge of the belt to avoid the crowned center of the pulley.

Rubber belts shall be friction-surfaced and the duck shall be thoroughly impregnated with a good grade of rubber.

Rubber belts shall be stitched, except at the splice, with only such stitching as is necessary in good manufacturing practice.

The several plies shall be thoroughly cemented together with first-class rubber compound, making adhesion between the plies of the duck sufficient to withstand the following test:

A strip 1 in. wide shall be cut crosswise or longitudinally from the belt and suspended vertically. A ply shall be stripped down and a 16-lb. weight fastened to it. This weight shall not cause a separation of the plies at a greater rate than 1 in. per min.

AXLE AND WHEELS DIVISION REPORT

Division Personnel

C. C. Carlton, *Chairman*	Motor Wheel Corporation
C. S. Dahlquist, *Vice-Chairman*	Cleveland
R. S. Begg	Jordan Motor Car Co., Inc.
L. R. Buckendale	Timken-Detroit Axle Co.
T. V. Buckwalter	Timken Roller Bearing Co.
R. J. Burrows	Clark Equipment Co.
L. W. Close	Bock Bearing Co.
J. Coapman	Russel Motor Axle Co.
H. E. Derr	International Harvester Co.
G. W. Dunham	Savage Arms Corporation
F. W. Gurney	Gurney Ball Bearing Co.
F. P. Hall, Jr.	Salisbury Axle Co., Inc.
G. W. Harper	Columbia Axle Co.
G. L. Lavery	West Steel Casting Co.
	Tire and Rim Association
A. M. Laycock	Waukesha Motor Co.
	Detroit Steel Products Co.
H. V. Ludwick	Budd Wheel Corporation
C. T. Myers	Consulting Engineer
O. J. Rohde	Wire Wheel Corporation of America
F. A. Shuler	Shuler Axle Co.
F. S. Spring	Courier Motors Co.

FRONT-WHEEL MOUNTINGS

(Proposed Extension of S.A.E. Recommended Practice)

As a result of further consideration, the Axle and Wheels Division recommends the passenger-car front-wheel dimensions given in Table 2 for adoption as an extension of the present S.A.E. Recommended Practice for Front-Axle Hubs, page F1b of the S.A.E. HANDBOOK. These dimensions will complete the present recommended practice for inch-size taper roller bearing front-axle hubs for passenger-cars and motor trucks.

[A meeting of the Axle and Wheels Division will be held on the morning of June 19 to review the report herein submitted, as certain dimensions have been questioned. Any revisions decided upon at that time will be submitted at the afternoon session of the Standards Committee Meeting.]

TABLE 2—PASSENGER-CAR FRONT-WHEEL WOOD HUBS

Hub Size	Outside Diameter of Hub	Distance Between Flanges	Flange Diameter	Flange Fillet-Radius	Bolt-Circle Diameter	No. of Bolts	Bolt Size[1]	Hub-Cap Thread
R0	2.1830 2.1860	1¼	6	3/16	5	6	3/8	2 1/8-24
R1	3.0625 3.0655	1¼	7	1/4	5¾	12	7/16	2 5/8-16
R2	3.5000 3.5030	1⅜	7¼	1/4	6	12	7/16	2 5/8-16
R3	3.6875 3.6905	1½	7⅝	3/8	6¼	12	7/16	3 -16
R4	3.8125 3.8155	1¾	8	3/8	6¼	12	7/16	3 3/4-16

[1] Machine screw bolts.

Note: The data in the table apply to wheels with wood or steel felloes, that is to all wheels having wood hubs.

TENON HOLES FOR PNEUMATIC-TIRE FELLOES

(Proposed S.A.E. Recommended Practice)

As a result of the increasing use of wood wheels with steel felloes, the Axle and Wheels Division recommends the adoption as S.A.E. Recommended Practice of the following table of tenon-hole sizes for steel felloes.

TABLE 3—TENON-HOLE DIAMETERS FOR PNEUMATIC TIRE WOOD WHEELS WITH STEEL FELLOES

Nominal Tire Cross-Section Diameter, In.	Spoke Size, In.	Tenon-Hole Diameter, In.
3½ or 4	1¼	½
4	1⅜	5/8
4½	1½	5/8
5	1¾	¾

The dimensions proposed are used extensively at the present time, the recommendation being submitted for the purpose of recognizing what is considered by the industry to be standard. Tenon-hole diameters have not been recommended for wheels carrying larger than 5-in. rims, as the steel felloe is not used on the larger sizes.

BALL AND ROLLER BEARINGS DIVISION REPORT

Division Personnel

F. W. Gurney, *Chairman*	Gurney Ball Bearing Co.
T. V. Buckwalter, *Vice-Chairman*	Timken Roller Bearing Co.
J. T. R. Bell	Rollway Bearing Co., Inc.
G. R. Bott	Norma Co. of America
H. E. Brunner	S. K. F. Industries, Inc.
E. R. Carter, Jr.	Fafnir Bearing Co.
D. F. Chambers	Bearings Co. of America
L. W. Close	Bock Bearing Co.
L. A. Cummings	Standard Steel & Bearings, Inc.
G. W. Dunham	Savage Arms Corporation
F. G. Hughes	New Departure Mfg. Co.
G. L. Miller	Gilliam Mfg. Co.
R. G. Schaffner	Bower Roller Bearing Co.
W. R. Strickland	Cadillac Motor Car Co.
R. E. Wells	Hyatt Roller Bearing Co.
H. Wickland	U. S. Ball Bearing Mfg. Co.

METRIC-TYPE THRUST BALL-BEARINGS

(Proposed Extension of S.A.E. Standard)

The Ball and Roller Bearings Division recommends that the present S.A.E. Standard for Metric-Type Thrust Ball-Bearings, pp. C39, C40, C41, C42 of the S.A.E. HANDBOOK, which specifies tolerances only, be extended by the addition of the definite boundary dimensions which were printed on pp. 531, 532, 533 and 534 of the December, 1922, issue of THE JOURNAL.

The boundary dimensions, which were referred back to the Ball and Roller Bearings Division by the Standards Committee in January, 1923, are resubmitted for approval to recognize the existing practice of four

TABLE 4—LIGHT-SERIES METRIC ROLLER-BEARING DIMENSIONS

Bearing No.	Inside Diameter			Outside Diameter			Width, In. Plus or Minus 0.020	Corner Radius Cups and Cones	Eccentricity Tolerances of Races, In.	
	Mm.	In.	Tolerances in Inches Minus 0.0000 Plus	Mm.	In.	Tolerances in Inches Minus 0.0000 Plus			Inner	Outer
L 04	20	0.78740	0.0010	47	1.85040	0.0010	3/4	3/64	0.0010	0.0012
L 05	25	0.98425	0.0010	52	2.04725	0.0010	3/4	3/64	0.0010	0.0012
L 06	30	1.18110	0.0010	62	2.44095	0.0010	3/4	3/64	0.0010	0.0012
L 07	35	1.37795	0.0010	72	2.83465	0.0010	7/8	3/64	0.0010	0.0012
L 08	40	1.57481	0.0010	80	3.14962	0.0010	1	3/64	0.0010	0.0012
L 09	45	1.77166	0.0010	85	3.34647	0.0010	1	3/64	0.0010	0.0016
L 10	50	1.96851	0.0010	90	3.54332	0.0010	1	3/64	0.0010	0.0016
L 11	55	2.16536	0.0010	100	3.93702	0.0010	1 1/16	3/64	0.0010	0.0016
L 12	60	2.36221	0.0010	110	4.33072	0.0010	1 1/8	3/64	0.0010	0.0016
L 13	65	2.55906	0.0010	120	4.72443	0.0010	1 1/8	3/64	0.0010	0.0016
L 14	70	2.75591	0.0010	125	4.92128	0.0010	1 1/8	3/64	0.0010	0.0016
L 15	75	2.95277	0.0010	130	5.11813	0.0010	1 1/16	3/64	0.0010	0.0016
L 16	80	3.14962	0.0010	140	5.51183	0.0010	1 1/8	3/64	0.0012	0.0018
L 17	85	3.34647	0.0012	150	5.90554	0.0012	1 3/4	1/16	0.0012	0.0018
L 18	90	3.54332	0.0012	160	6.29924	0.0012	2	1/16	0.0012	0.0018
L 19	95	3.74107	0.0012	170	6.69294	0.0012	2 1/16	1/16	0.0012	0.0018
L 20	100	3.93702	0.0012	180	7.08664	0.0012	2 1/8	1/16	0.0012	0.0018
L 21	105	4.13387	0.0012	190	7.48035	0.0012	2 1/8	1/16	0.0012	0.0018
L 22	110	4.33072	0.0012	200	7.87405	0.0012	2 1/4	1/16	0.0012	0.0018

American manufacturers that are producing metric-type thrust ball-bearings at the present time according to the standards proposed.

Standards covering inch-type thrust ball-bearings were formulated by the Division in 1917 and were adopted by the Society the same year. They are printed on pp. C34 to C39 of the S.A.E. HANDBOOK.

METRIC-TYPE ROLLER BEARINGS

(Proposed Revision of S.A.E. Standards)

The Ball and Roller Bearings Division recommends that the present S.A.E. Standards for Metric-Type Roller Bearings, pp. C43 and C44 of the S.A.E. HANDBOOK, be revised to conform to the dimensions given in Tables 4 and 5.

As revised, the inside and the outside diameters correspond to the inside and the outside diameters for the same sizes of annular ball bearings for the light and the medium series, pp. C26 and C28 of the S.A.E. HANDBOOK. The widths are in accord with the widths of the wide-type annular ball-bearings, p. C31 of the S.A.E. HANDBOOK. The serial designations have been revised, letters "L" and "M", standing for "Light" and "Medium", being prefixed to numbers indicating one-fifth of the inside diameters in millimeters. The tolerances for the inside and the outside diameters and the widths conform to those for inch-type roller bearings rather than following those of the ball-bearings because of the inherent difference in the character of the bearings and the methods of installation.

In recommending these revisions, the Division feels that there is sufficient demand for standard metric-type roller bearings that are interchangeable with wide or double-row type ball-bearings to warrant retaining the present standards, especially as this type bearing is manufactured in Europe to a certain extent. The Roller Bearing Subdivision, which originated the above recommendation, is working on the standardization of inch-type roller bearings. Although no real progress has been made to date, it is recognized the standard inch-type roller bearings are of extreme importance to the industry owing to their extensive use. The metric-type

TABLE 5—MEDIUM-SERIES METRIC ROLLER-BEARING DIMENSIONS

Bearing No.	Inside Diameter			Outside Diameter			Width, In. Plus or Minus 0.020	Corner Radius Cups and Cones	Eccentricity Tolerances of Races, In.	
	Mm.	In.	Tolerances in Inches Minus 0.0000 Plus	Mm.	In.	Tolerances in Inches Minus 0.0000 Plus			Inner	Outer
M04	20	0.78740	0.0010	52	2.04725	0.0010	7/8	3/64	0.0010	0.0012
M05	25	0.98425	0.0010	62	2.44095	0.0010	1	3/64	0.0010	0.0012
M06	30	1.18110	0.0010	72	2.83465	0.0010	1 1/16	3/64	0.0010	0.0012
M07	35	1.37795	0.0010	80	3.14962	0.0010	1 1/8	3/64	0.0010	0.0012
M08	40	1.57481	0.0010	90	3.54332	0.0010	1 1/16	3/64	0.0010	0.0012
M09	45	1.77166	0.0010	100	3.93702	0.0010	1 1/16	3/64	0.0010	0.0016
M10	50	1.96851	0.0010	110	4.33072	0.0010	1 1/4	3/64	0.0010	0.0016
M11	55	2.16536	0.0010	120	4.72443	0.0010	1 1/8	3/64	0.0010	0.0016
M12	60	2.36221	0.0010	130	5.11813	0.0010	2 1/8	3/64	0.0010	0.0016
M13	65	2.55906	0.0010	140	5.51183	0.0010	2 1/16	3/64	0.0010	0.0016
M14	70	2.75591	0.0010	150	5.90554	0.0012	2 1/2	3/64	0.0010	0.0016
M15	75	2.95277	0.0010	160	6.29924	0.0012	2 1/16	3/64	0.0010	0.0016
M16	80	3.14962	0.0010	170	6.69294	0.0012	2 1/16	3/64	0.0012	0.0018
M17	85	3.34647	0.0012	180	7.08664	0.0012	2 1/8	1/16	0.0012	0.0018
M18	90	3.54332	0.0012	190	7.48035	0.0012	2 1/8	1/16	0.0012	0.0018
M19	95	3.74017	0.0012	200	7.87405	0.0012	3 1/16	1/16	0.0012	0.0018
M20	100	3.93702	0.0012	215	8.46460	0.0012	3 1/4	1/16	0.0012	0.0018
M21	105	4.13387	0.0012	225	8.85830	0.0012	3 1/16	1/16	0.0012	0.0018
M22	110	4.33072	0.0012	240	9.44886	0.0012	3 5/8	1/16	0.0012	0.0018

roller bearing standards are considered necessary, however, for those manufacturers using this type of bearing.

Shaft and Housing Fits and Tolerances for Ball Bearings

(Proposed Cancellation of General Information)

The ball-bearing manufacturers have agreed that it is not practicable to recommend shaft and housing fits and tolerances for ball-bearings because each application usually depends upon particular conditions which must be met individually. The Ball and Roller Bearings Division therefore recommends that the present general information published on p. C33d of the S.A.E. Handbook be cancelled.

ELECTRICAL EQUIPMENT DIVISION REPORT

Division Personnel

F. W. Andrew, *Chairman*	Eisemann Magneto Corporation
T. L. Lee, *Vice-Chairman*	North East Electric Co.
C. R. Alling	Underwriters' Laboratories
Azel Ames	Kerite Insulated Wire & Cable Co.
W. A. Chryst	Dayton Engineering Laboratories Co.
S. F. Evelyn	Continental Motors Corporation
C. F. Gilchrist	Electric Auto-Lite Corporation
W. S. Haggott	Packard Electric Co.
F. C. Kroeger	Remy Electric Co.
B. M. Leece	Leece-Neville Co.
A. D. T. Libby	Splitdorf Electrical Co.
W. P. Loudon	Westinghouse Electric & Mfg. Co.
Charles Marcus	Bijur Motor Appliance Co.
Ernest Wooler	Cleveland Automobile Co.

Magnet Wire

(Proposed S.A.E. Standard)

The Electrical Equipment Division recommends the adoption of the accompanying magnet wire specifications as S.A.E. Standard. These specifications were formulated by a Subdivision, the personnel of which is as follows:

Chas. Marcus, *Chairman,*	Bijur Motor Appliance Co.
J. A. Harvey	Harvey Mfg. Co.
C. F. Hood	American Steel & Wire Co.
H. J. Horn	John A. Roebling's Sons Co.
L. S. Horner	Acme Wire Co.
D. J. Jackson	Dudlo Mfg. Co.
W. A. D. Peaslee	Belden Mfg. Co.
F. M. Potter	Rome Wire Co.
R. G. Thompson	North-East Electric Co.

As submitted, the specifications proposed are practically in accord with the specifications that will be proposed by the Subcommittee on Magnet Wire appointed by the Sectional Committee on Insulated Wires and Cables.

[A Division meeting will be held on Tuesday, June 19, the day of the Standards Committee meeting, at which it is anticipated that a supplementary report will be approved for submission to the Standards Committee which will cover desirable dimensions for enameled wire.]

PROPOSED SPECIFICATIONS FOR MAGNET WIRE

I. BARE COPPER

All bare copper wire used shall meet the requirements of the latest specifications of the American Society for Testing Materials for soft or annealed copper wire (Serial Designation B3-15).

II. ENAMEL

(1) *Uniformity.*—The wire shall be coated with a continuous insulating film of enamel of uniform thickness according to the dimensions shown in Table 6.

[Tables of dimensions for enamel-covered wire will be submitted by the Electrical Equipment Division at the Standards Committee meeting on June 19, 1923.]

(2) *Quality.*—The enamel coating shall be tough and elastic, and possess a hard and smooth surface. It shall be non-hygroscopic, insoluble in mineral oils, and such as to pass all tests hereinafter mentioned. All tests shall be made on wire taken directly from the spool.

(3) *Elongation Test.*—Enamel wire having a bare wire diameter of 0.0179 in. (No. 25 A.w.g.) and smaller, shall withstand elongation to the breaking-point without the enamel rupturing or flaking so that it is perceptible to the naked eye.

(4) *Mandrel Tests for Flexibility.*—At 60 to 80 deg. fahr. (15 to 27 deg. cent.) when enamel wire is wrapped as per Table 7, the enamel shall not rupture or flake so as to be perceptible to the naked eye.

(5) *Temperature Tests.*—The flexibility of the enamel shall not be impaired by baking at 212 deg. fahr. (100 deg. cent.) for 48 hr., nor lose its original gloss or luster, and the enamel shall not soften. After being allowed to cool, the enamel wire shall be capable of being wound around a mandrel as shown in Table 7, without the enamel rupturing or flaking so that it is perceptible to the naked eye.

TABLE 7—MANDREL SIZES FOR MECHANICAL TEST OF ENAMEL

Wire Size, A.w.g.	Mandrel Diameter Number of Times
8-11	5½
12-14	4
15-20	3
21-24	2

(6) *Electrical Tests.*—Dielectric tests may be conducted by either the mandrel test method or the twist test method, as outlined in the following paragraphs:

Mandrel Test.—Two layers of enameled wire shall be wound one on top of the other over a smooth mandrel of insulating material such as bakelite, hard rubber, fiber or similar material, 1 in. in diameter. The length of the winding along the mandrel shall be 1 in. and the tension applied shall not stretch or elongate the enamel wire. When alternating-current voltage at 25 to 100 cycles per second is applied between the layers the enamel shall not be punctured at less than the voltage given in Table 8. The test shall be made by applying a low voltage and raising the voltage gradually until puncture occurs. If, upon testing a sample from any spool or reel of wire, it should fail to meet this test, tests upon

TABLE 8—VOLTAGE FOR DIELECTRIC TESTS

Wire Size, A.w.g.	Voltage, A.C.
40 to 30 incl.	300
29 to 25 incl.	600
24 and larger	900

The above voltages are effective values as read on the voltmeter at breakdown.

two additional samples shall be made. If two of the three fail, the wire shall be rejected, but if two of the three withstand the test, it shall be accepted.

The transformer used in making this test shall be used under the conditions set forth in the

standardization rules of the American Institute of Electrical Engineers as to size and method of control to prevent wave distortion.

TABLE 9—TWISTS FOR DIELECTRIC TEST

Wire Size, A.w.g.	Twists per Inch
40-31	10
30-25	8
24-20	6
19-16	3
15 and larger	2

Twist Test.—Two strands of enameled wire shall be twisted together for a length of 4 in., the number of twists per inch corresponding to Table 9. The tension applied in twisting shall not be such as to stretch the wire, and the twist shall be uniform.

An alternating current of 120 volts shall be applied and gradually increased to the maximum voltages shown in Table 8 below which the enamel should not be punctured.

(7) *Effects of Oils and Waxes.*—The enamel coating shall withstand the action of transformer oil, neutral mineral-oil, lard oil and neutral waxes of a maximum temperature of 250 deg. fahr. (121 deg. cent.) for 48 hr. without injury to the enamel.

(8) *Effects of Impregnation in Varnishes.*—The enamel insulation of wire wound in coils shall not be injuriously affected by impregnation in insulation varnishes with benzine or petroleum naphtha vehicle or thinner, if properly used.

III. SINGLE COTTON
IV. DOUBLE COTTON
V. SINGLE COTTON ENAMEL
VI. DOUBLE COTTON ENAMEL

(1) *Quality.*—The covering shall consist of unbleached cotton yarn of a suitable quality obtainable for purposes of insulation.

The wrapping of yarn shall be continuous and firmly applied. Double cotton covering shall be wrapped in opposite directions.

(2) *Amount of Covering.*—Amount of covering shall be in accordance with Tables 10 and 11.

TABLE 10—MAXIMUM PERMISSIBLE ADDITIONS FOR SINGLE COTTON-COVERED WIRE

Bare Wire Diameter, In., Inclusive	Maximum Addition, In.
0.4600 to 0.1285	0.0080
0.1144	0.0070
0.1019	0.0060
0.0907 to 0.0284	0.0050
0.0253 to 0.0056	0.0045
0.0050 to 0.0031	0.0040

The minimum permissible addition to the diameter of bare wire is 85 per cent of the specified maximum.

TABLE 11—MAXIMUM PERMISSIBLE ADDITIONS FOR DOUBLE COTTON-COVERED WIRE

Bare Wire Diameter, In., Inclusive	Maximum Addition, In.
0.4600 to 0.1819	0.0160
0.1620 to 0.1285	0.0140
0.1144	0.0120
0.1019	0.0110
0.0907 to 0.0284	0.0095
0.0253 to 0.0056	0.0085
0.0050 to 0.0031	0.0080

The minimum permissible addition to the diameter of bare wire is 85 per cent of the specified maximum.

(3) *Mechanical Test for Density.*—When the wire is bent around a radius equal to five times the diameter of the wire, the cotton wrapping shall to the naked eye not open sufficiently to expose the bare wire beneath.

(4) *Insulation Tests.*—Due to the hygroscopic quality of the covering herein discussed it has not been found feasible to make a recommendation covering this test.

VII. SINGLE SILK
VIII. DOUBLE SILK
IX. SINGLE SILK ENAMEL
X. DOUBLE SILK ENAMEL

(1) *Quality.*—Covering shall consist of insulating silk yarn of a quality suitable for purposes of insulation.

The wrapping of silk yarn shall be continuous and firmly applied. Double silk covering shall be wrapped in opposite directions.

(2) *Amount of Covering.*—Amount of covering shall be in accordance with Table 12.

TABLE 12—MAXIMUM PERMISSIBLE ADDITIONS FOR SINGLE AND DOUBLE SILK-COVERED WIRE

Bare Wire Diameter, In., Inclusive	Maximum Addition, In. Single Covered	Maximum Addition, In. Double Covered
0.0570 to 0.0031	0.0020	0.0040

The minimum permissible addition to the diameter of bare wire is 75 per cent of the specified maximum.

(3) *Mechanical Test for Density.*—When the wire is bent around a radius equal to five times the diameter of the wire, the silk wrapping shall be to the naked eye not open sufficiently to expose the bare wire beneath.

(4) *Insulation Tests.*—Due to hygroscopic quality of the covering herein discussed it has not been found feasible to make a recommendation covering insulation tests.

XI. PACKING FOR ALL WIRES

(1) *Spool or Reel Dimensions.*—All wire is to be packed on standard spools as per Table 13.

TABLE 13—SPOOL DIMENSIONS

Wire Size, A.w.g.	Maximum Diameter of Head, In.	Maximum Length of Spool Overall, In.	Minimum Diameter of Arbor, In.
8-20	24	12	1¼
10-20	18	12	1¼
12-20	12	8½	1¼
14-20	9	8½	1¼
20-26	6	4¼	⅝
25-33	4½	4	⅝
25-37	4	4	⅝
34-40	3	4	⅝
38-44	2½	4	⅝

(2) *Continuity of Winding.*—The wire shall be in one continuous length in each package. Such joints as may be necessary to bring the wire up to the minimum weight called for in Table 13 shall be made by brazing in a good workmanlike manner so that the diameter of the wire after brazing is substantially the same as in the other portion of the wire, and the joint must be so smoothed-down that there will be no rough places to cut the insulation. The wire at a joint must be substantially identical in softness and dimensions with the rest of the wire and have at least 95 per cent of its strength.

(3) *Density of Winding.*—The wire shall be wound on spools under such a tension as will give an even and compact winding. A soft body of wire on the spool will not be satisfactory. On 0.0201 in. (No. 24 A.w.g.) and finer the inner end of the wire on a spool must be brought out so that it will be available.

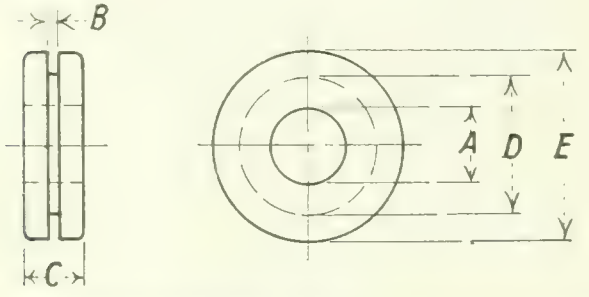
Rubber Bushings

(Proposed S. A. E. Standard)

The Electrical Equipment Division recommends the doption of the accompanying dimensions for soft rubber bushings or grommets for use in installing automotive electric wiring, tubing and speedometer drives, here they pass through sheet metal, to prevent chafing. he proposed standard was formulated by the Subivision on Automobile Wiring, the personnel of which s given below.

W. S. Haggott, *Chairman*	Packard Electric Co.
H. B. Burley	Boston Insulated Wire & Cable Co.
M. L. Hillmer	Remy Electric Co.
B. M. Leece	Leece-Neville Co.
B. M. Smarr	General Motors Corporation
C. H. Williams	Studebaker Corporation of America
Ernest Wooler	Cleveland Automobile Co.

In addition to the subjects of Automobile Wiring and Rubber Bushings, the Subdivision was also assigned he subjects of Cable Terminals and Clips, reports overing these being given hereinafter. The work on

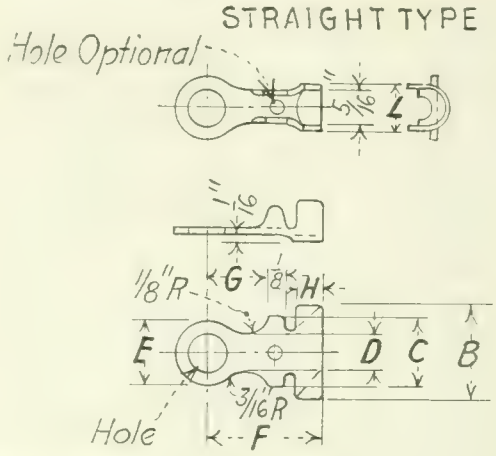


A	*B*	*C*	*D*	*E*
17/64	1/16	5/16	15/32	
17/64	3/16	7/16	15/32	
	1/16		17/32	
	1/16		17/32	
25/64	1/16		21/32	
	1/16		21/32	
	1/16	5/16	27/32	1 1/16
41/64	3/16	5/16	27/32	1 1/16
41/64	1/16	5/16	31/32	1 3/16
41/64	3/16	7/16	31/32	1 3/16
49/64	1/16	5/16	1 3/32	1 3/16
49/64	3/16	7/16	1 3/32	1 3/16
1 1/32	1/16	5/16	1 11/32	1 9/16
1 1/32	1/16	7/16	1 11/32	1 9/16

Material.—Rubber sufficiently soft to permit the bushing or grommet to be inserted in a hole of the size recommended without being cut.

Note.—The recommended size for the hole in the metal in which a bushing or grommet is inserted shall be 1/32-in. larger than dimension *D*.

automobile wiring, which covers the standardization of a color code for the cable braid of the principal circuits, is still in progress.



Recommended Size of Cable	Size of Screw	Diameter of Hole	Terminal Dimensions *B*	*C*	*D*	*E*	*F*	*G*	*H*	*L*	Thickness
Nos. 16, 14, 12	No. 8 or 10	0.201	1/4	1/2	3/16	3/8	11/16	3/16	7/32	7/32	0.030
Nos. 12, 10	No. 8 or 10	0.201	1/4	5/8	7/16	1/2	13/16	3/16	7/32	7/32	0.030
Nos. 12, 10	1/4	9/32	5/16	5/8	7/16	1/2	1 1/16	3/16	7/32	7/32	0.040
Nos. 12, 10	5/16	11/32	5/16	5/8	7/16	1/2	1 1/16	3/16	7/32	7/32	0.040
Nos. 12, 10	5/16	11/32	5/16	5/8	7/16	1/2	1 1/16	3/16	7/32	7/32	0.040

Alternate Construction. The wings which clamp the cable may be cut diagonally as indicated by dotted lines

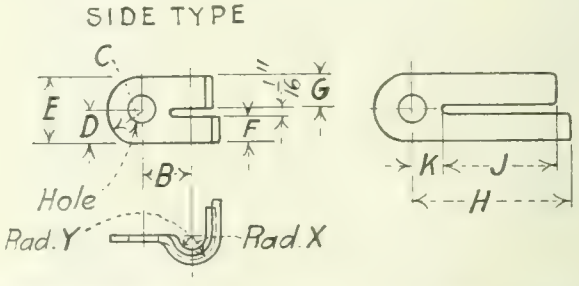
Material.—Soft sheet copper, S. A. E. Specification No. 71, or Soft Sheet Brass, S. A. E. Specification No. 70.

Note.—Terminals must be free from burrs, corrosion or any foreign matter. The temper of terminals must be sufficiently soft to permit of the terminals being assembled with wings closed and not show any fracture or cracks which will impair the strength of the assembly.

Cable Terminals

(Proposed Revision of S. A. E. Standard)

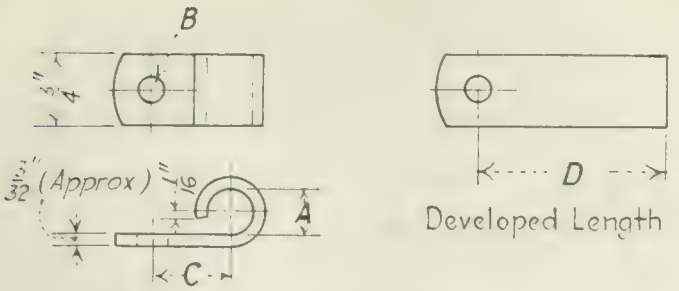
The Electrical Equipment Division submits four types of cable terminal for adoption in place of the present cable terminal standards, pp. B21 and B22 of the S.A.E.



Recommended Size of Cable	Size of Screw	Diameter of Hole	Terminal Dimensions *B*	*C*	*D*	*E*	*F*	*G*	*H*	*J*	*K*	*Y*	*X*	Thickness
Nos. 16, 14, 12	No. 8 or 10	0.201	1/4	1/2	3/16	1/4	11/16	3/16	1/4	5/64	5/64			0.040
Nos. 12, 10	No. 8 or 10	0.201	1/4	1/2	3/16	1/4	11/16	3/16	1/4	5/64	5/64			0.040
Nos. 12, 10	1/4	9/32	5/16	1/2	3/16	1/4	11/16	1/2	5/64	5/64				0.040
Nos. 12, 10	5/16	11/32	5/16	5/8	7/16	1/2	11/16	5/16	7/64	5/64				0.040
Nos. 12, 10	5/16	11/32	5/16	5/8	7/16	1/2	11/16	5/16	7/64	5/64				0.040

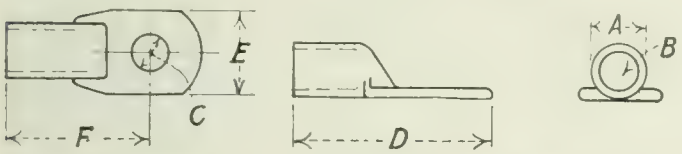
Material.—Soft Sheet Copper, S. A. E. Specification No. 71, or Soft Sheet Brass, S. A. E. Specification No. 70.

Note.—Terminals must be free from burrs, corrosion or any foreign matter. The temper of terminals must be sufficiently soft to permit of the terminals being assembled with wings closed and not show any fracture or cracks which will impair the strength of the assembly.



Size	Wire Size, A.w.g.	A	B	C	D
4	4	5/16	9/32	11/16	1 13/32
4	4	5/16	11/32	11/16	1 5/32
1	2	1/4	11/32	3/4	2
1	1	1/4	11/32	3/4	2
0	0	1/2	11/32	13/16	2 9/32
0	00	1/2	11/32	13/16	2 9/32

Material.—Soft Sheet Copper, S. A. E. Specification No. 71.



Size A	Wire Size, A.w.g.	B	C	D	E	F
3/8	4	0.285	9/32	1 11/32	17/32	1 1/16
3/8	4	0.285	11/32	1 11/32	17/32	1 1/16
7/16	2	0.336	11/32	1 1/2	5/8	1 5/32
7/16	2	0.336	13/32	1 1/2	5/8	1 5/32
1/2	1	0.398	11/32	1 3/4	3/4	1 11/32
1/2	1	0.398	13/32	1 3/4	3/4	1 11/32
9/16	0	0.461	13/32	2	13/16	1 9/16
5/8	00	0.511	15/32	2 1/8	29/32	1 5/8

Material.—Soft Sheet Copper, S. A. E. Specification No. 71.

HANDBOOK. For generators, switches and meters, the straight and side types of terminals are proposed as given in the accompanying Tables.

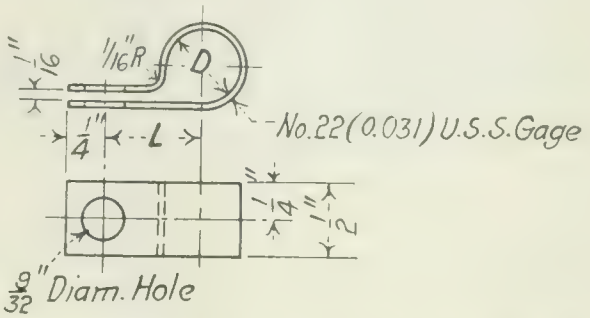
For starting-motor cable terminals, two types are proposed: the rolled type, which represents an extension of the existing standard, and the straight type. The dimensions proposed are given in the accompanying Tables.

The report was prepared by the Subdivision on Automobile Wiring when it was found that the existing cable terminal standards were not used as extensively as it was hoped they would be when the standards were originally approved. It is felt that the revised standards will be used by practically all manufacturers as they follow closely the standards already established by the terminal manufacturers for the greater part of their production.

CLIPS

(Proposed S.A.E. Standard)

The Electrical Equipment Division recommends the adoption as S.A.E. Standard of the accompanying table of clip dimensions. The diameters selected permit the



D	L	D	L	D	L
1/16	15/32	1/2	5/8	1	7/8
1/4	1/2	9/16	21/32	1 1/8	15/16
5/16	17/32	5/8	11/16	1 7/16	1 1/32
3/8	9/16	3/4	3/4		
7/16	19/32	7/8	13/16		

Material.—Sheet or Strip Steel, S. A. E. Steel No. 1010

use of the proposed clips for cable, conduit and flexible tubing. They may also be used for gasoline tubing.

STARTING-MOTOR MOUNTINGS

(Proposed Extension of S.A.E. Recommended Practice)

The present S.A.E. Recommended Practice for the barrel type of starting-motor mounting, p. B16b of the S.A.E. HANDBOOK, specifies limits of 3.496 to 3.499 in. for the diameter of the barrel. The diameter of the bore in the flywheel housing in which the barrel is mounted is not specified.

After obtaining the recommendations of the Engine Division members as to what the limits for the bore should be, the Electrical Equipment Division recommends that the present standard be revised by the addition of the following note.

> The limits of the bore in the flywheel housing in which the barrel type of starting motor is mounted, shall be 3.500 to 3.503 in.

These limits permit a fit of from 0.001 to 0.007 in., which is considered satisfactory as in production the diameter of the starting-motor barrel runs to the high limit.

ELECTRIC VEHICLE DIVISION REPORT

Division Personnel

E. L. Clark, *Chairman*	Commercial Truck Co.
Karl Probst, *Vice-Chairman*	Milburn Wagon Co.
G. L. Bixby	Detroit Electric Car Co.
A. K. Brumbaugh	Autocar Co.
J. G. Carroll	Walker Vehicle Co.
H. M. Pierce	Ward Motor Vehicle Co.
F. E. Queeney	Lansden Co., Inc.
C. R. Skinner, Jr.	New York Edison Co.

BATTERY TRAYS FOR ELECTRIC TRUCKS

(Proposed S.A.E. Recommended Practice)

About a year and a half ago the need for standardizing the sizes and the arrangement of storage-battery trays for electric trucks was brought to the division's atten-

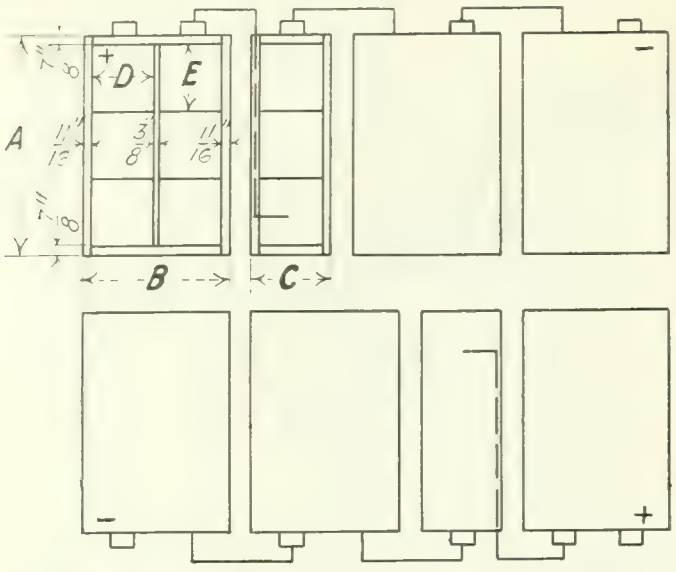


FIG. 1

Nominal Truck Capacity, Tons	Range of Jar Widths, In. Inclusive	A Max.	B Max.	C Max.	D	E	Fig. No.
1/2	Up to 4 5/16	20 1/2	10 1/2	5 3/4	4 5/16	6 5/16	1
1	4 5/16 to 5 1/16	20 1/2	12	6 1/2	5 1/16	6 5/16	1
2	5 9/16 to 6 7/8	22 9/16	14 7/8	7 11/16	6 1/4	6 7/8	1
3 1/2	7 1/8 to 8 1/8	27 11/16	9 7/8		8 1/8	6 1/4	2
5	8 7/8 to 10 5/8	27 11/16	12 1/8		10 7/8	6 1/4	2

Maximum height of all lead-acid tray assemblies shall be 16 in.

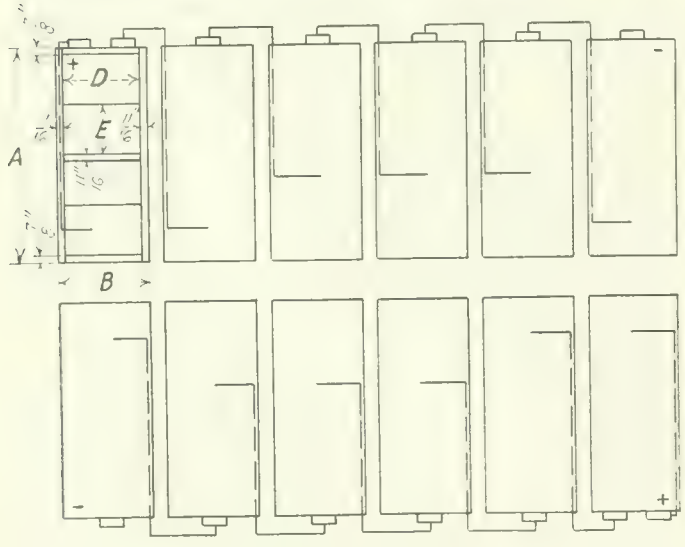


FIG. 2

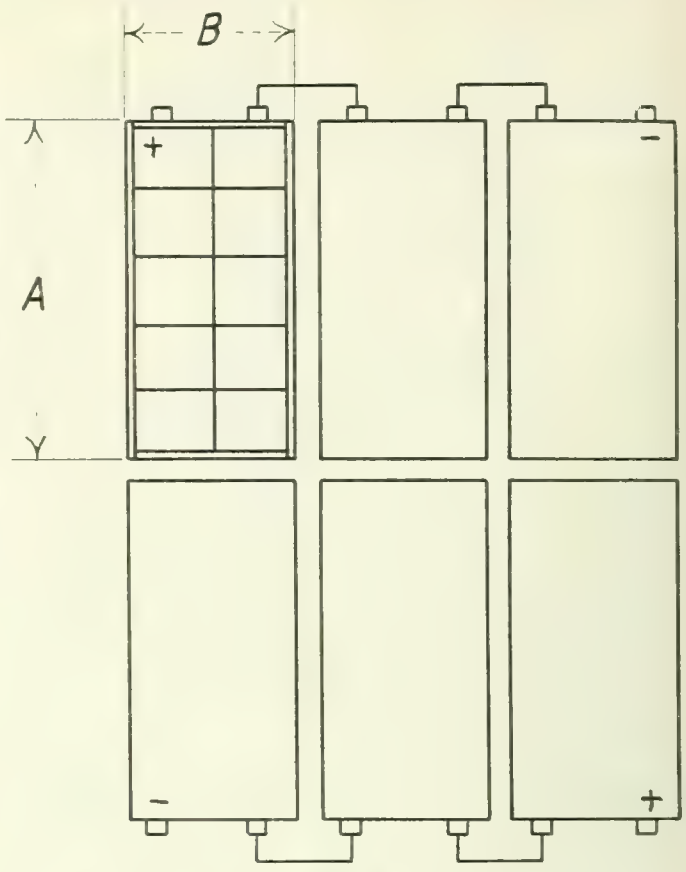


FIG. 3

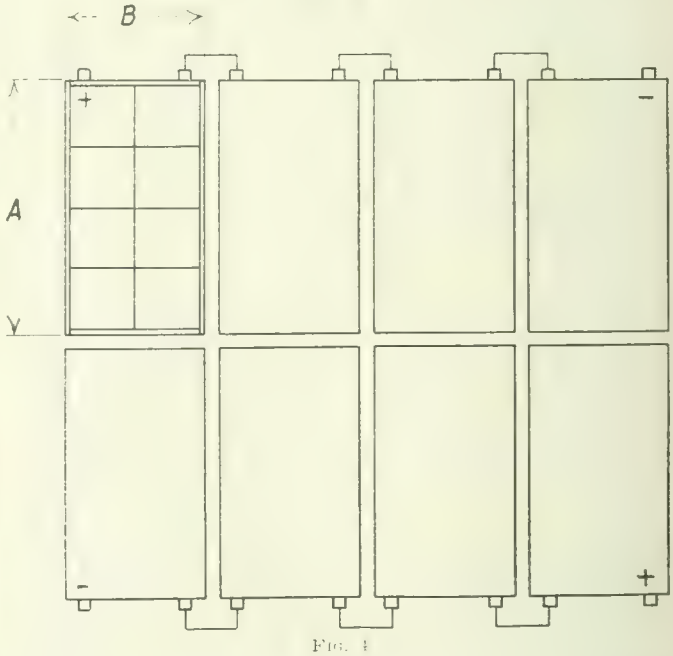


FIG. 4

tion. As electric trucks are usually operated in fleets, it is important that adequate provision be made for removing the batteries for recharging and replacing them with fully charged batteries. Operators of fleets of more than one make of truck have been particularly troubled in this connection and have evidenced a strong desire for a remedy. A Subdivision comprising E. L. Clark and Bruce Ford was appointed to study the situation and prepare a recommendation in 1922. Data were gathered and several meetings held at which tentative reports were thoroughly considered.

The Division now presents the following report for adoption as S.A.E. Recommended Practice in the belief that the dimensions recommended, if adhered to by the battery and electric-truck manufacturers in the future, will eliminate the trouble that has been experienced in charging the batteries and will materially reduce the number of battery sizes the battery manufacturers will have to make. The various types of cradle now used have been carefully considered and it is believed that the recommendation can be followed by all manufacturers with no serious changes in cradle design.

TABLE 5—NICKEL-IRON STORAGE-BATTERY TRAYS

Nominal Truck Capacity, Tons	Type of Battery	A[1]	B	Battery Height[2]	Fig. No.
½	A- 5	20½	12¼	15⅛	3
1	A- 6	23½	12¼	15⅛	3
	A- 7	26⅛	12¼	15⅛	3
2	A- 8	24⅛	12¼	15½	4
3½	A-10	26⅛	15½	15½	4
5	A-12	26⅛	18	16¼	4

[1] Including ¼-in. bumpers at both ends. In adding terminal plate subtract ¼ in. from terminal plate height.
[2] Maximum height of batteries in trays, with caps closed.

Charging-Plugs and Receptacles

(Proposed Revision of S. A. E. Standard)

As it has been ascertained that the S.A.E. Standard 150-amp. charging-plug and receptacle is used only on electric street-trucks, the 50-amp. charging-plug and receptacle being used on passenger vehicles and industrial trucks, the Electric Vehicle Division recommends that this distinction be specified in the present S.A.E. Standard for Charging-Plugs and Receptacles, p. B38 of the S.A.E. HANDBOOK.

Electric Vehicle Motors

(Proposed Revision of S.A.E. Recommended Practice)

The Electric Vehicle Division recommends that the present S.A.E. Recommended Practice for Electric Vehicle Motors, p. B41 of the S.A.E. HANDBOOK, be revised so that the recommendations for motor ratings shall read

> The rating of electric automobile propulsion motors shall be based on a temperature-rise not to exceed 65 deg. cent. (117 deg. fahr.) by thermometer, or 75 deg. cent. (135 deg. fahr.) by resistance after 4 hr. of continuous operation at normal rated load.
>
> The tests shall be made on a stand with the motor-covers arranged as in service.

The revised rating omits specifying at what room-temperature the test shall be made because it is impracticable to conduct tests with a constant room-temperature.

ENGINE DIVISION REPORT

Division Personnel

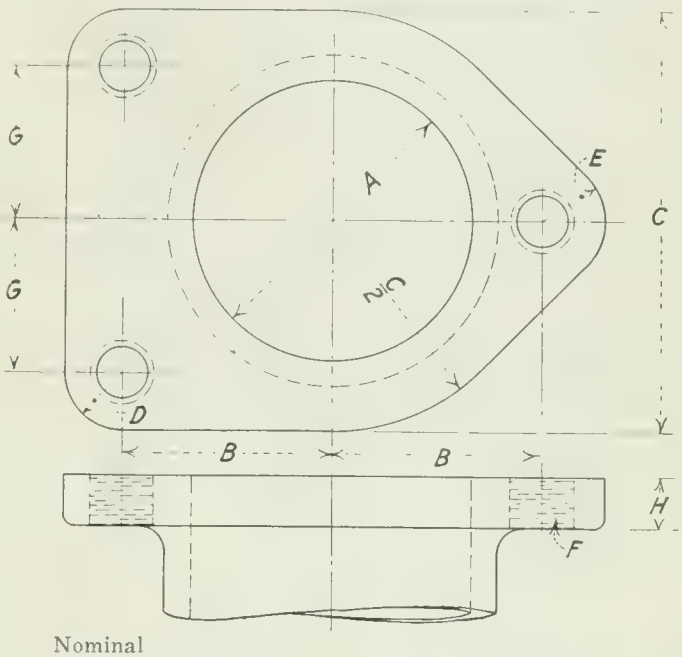
J. B. Fisher, *Chairman*	Waukesha Motor Co.
R. J. Broege, *Vice-Chairman*	Buda Co.
P. J. Dasey	Midwest Engine Co.
S. F. Evelyn	Continental Motors Corporation
P. E. Holt	Holt Mfg. Co.
A. F. Milbrath	Wisconsin Motor Mfg. Co.
Louis Schwitzer	Automotive Parts Co.
M. J. Steele	Packard Motor Car Co.
Joseph VanBlerck	Joseph VanBlerck Engine Corporation
W. C. Ware	Fay & Bowen Engine Co.

Carbureter Flanges

(Proposed Extension of S. A. E. Recommended Practice)

The Engine Division recommends that the present S.A.E. Recommended Practice for Carbureter Flanges, p. A8 of the S.A.E. HANDBOOK, be extended to include the accompanying three-bolt type carbureter flange for motorcycle engines. The dimensions proposed are used extensively at the present time, having been developed to meet the special requirements necessitated by the lack of space and the excessive vibration in motorcycles.

The Division also recommends, in view of the fact that since the original specification for carbureter flanges was adopted by the Society in 1912 and has come into almost universal use, that the status be changed from S.A.E. Recommended Practice to S.A.E. Standard.



Nominal Carbureter Size	A	B	C	D	T	F[1]	G	H
¾	1⅛	[illegible]	1¾	¼	¼	¼-24	⅝	¼
1	1⅛	[illegible]	1¾	¼	[illegible]	¼-24	⅝	¼
1¼	1⅜	1[illegible]	2[illegible]	[illegible]	[illegible]	[illegible]-18	¾	¼

[1] S. A. E. Form of Thread.

Engine Testing Forms

(Proposed Revision of S. A. E. Standard)

At the meeting of the Standards Committee in January, 1922, the recommendation of the Engine Division as to various revisions of the present S.A.E. Standard Engine Testing Forms was referred back for further consideration, particularly in reference to the temperature specified for recording the cold test and the Saybolt viscosity.

The original report specified temperatures of 150 and 350 deg. fahr. Action on this subject was deferred by the Engine Division until the report of the Lubricants Division on crankcase lubricating oils was approved by the Society. As the report, which is now printed on p. D151 of the S.A.E. HANDBOOK, specifies temperatures of 100 and 210 deg. fahr., the Engine Division recommends that the original recommendation of the Division be resubmitted for approval with the exception that the temperatures specified for recording the cold test and the Saybolt viscosity shall be 100 and 210 deg. fahr. The definite revisions proposed by the Engine Division follow:

SPECIFICATION SHEET B

Under Item No. 6, Cooling System, provide for recording the fan diameter, projected width of fan-blades and the ratio of fan speed to engine speed.

Under Item No. 32, Lubricating System, Type and

Description, provide for recording the cold test and the Saybolt viscosity at 100 and 210 deg. fahr.

Add a section entitled, Accessories, containing Item 33, Accessories Attached during Test, under which are to be listed the accessories attached to the engine during the test and conditions under which they operated.

LOG SHEET C

Add a note to the effect that it is recommended that results be corrected to a temperature of 60 deg. fahr. and 29.92 in. of mercury barometric pressure by using the formula.

$B.Hp._c = B.Hp._o \times (P_s/P_o) \times \sqrt{(T_o/T_s)}$

$B.Hp._c$ = corrected brake-horsepower

$B.Hp._o$ = observed brake-horsepower

P_o = observed barometric pressure in inches of mercury

P_s = standard barometric pressure in inches of mercury

T_o = observed absolute temperature in degrees fahrenheit

T_s = standard absolute temperature in degrees fahrenheit

CURVE SHEET D

Change the ordinates for the fuel consumption from "0.5 to 2.5" to "0.5 to 1.5" lb. per b.hp-hr. so that 4 ordinate lines will represent 0.1 lb. per b.hp-hr.

Insert the intermediate values for the brake-horsepower ordinates.

FRAMES DIVISION REPORT

Division Personnel

W. A. McKinley, *Chairman*	Detroit Pressed Steel Co.
C. C. Bowman, *Vice-Chairman*	Standard Motor Truck Co.
E. A. DeWaters	Buick Motor Co.
L. J. Fralick	Hydraulic Pressed Steel Co.
O. B. Harmon	Parish & Bingham Co.
Ernest Wooler	Cleveland Automobile Co.

Passenger-Car Frames

(*Proposed Cancellation of S. A. E. Recommended Practice*)

The Frames Division recommends that the present S.A.E. Recommended Practice for Passenger-Car Frames, p. H21 of the S.A.E. HANDBOOK, be cancelled. The recommended practice was adopted in 1915, at which time it was logical and satisfactory for existing conditions, but subsequent development has rendered it obsolete. It is felt that no standards should be set-up at this time for passenger-car frames as their design depends largely upon individual chassis and body design.

IRON AND STEEL DIVISION REPORT

Division Personnel

F. P. Gilligan, *Chairman*	Henry Souther Engineering Corporation
W. C. Peterson, *Vice-Chairman*	Atlas Steel Corporation
R. J. Allen	Rolls-Royce of America, Inc.
R. M. Bird	Bethlehem Steel Co.
H. T. Chandler	Metallurgist
A. L. Colby	Consulting Metallurgist
B. F. Courtright	Wisconsin Steel Co.
L. A. Danse	Cadillac Motor Car Co.
C. N. Dawe	Studebaker Corporation of America
B. H. DeLong	Carpenter Steel Co.
E. W. Ehn	Timken Roller Bearing Co.
A. P. Eves	International Harvester Co.
H. L. Greene	Willys-Overland Co.
G. F. Harper	Allis-Chalmers Mfg. Co.
W. H. Higgins, Jr.	Advance Rumely Co., Inc.
E. J. Janitzky	Illinois Steel Co.
J. B. Johnson	Air Service
F. C. Langenberg	Watertown Arsenal
F. E. McCleary	Dodge Bros.
C. S. Moody	Minneapolis Steel & Machinery Co.
J. H. Nelson	Wyman-Gordon Co.
G. L. Norris	Vanadium Corporation of America
W. H. Phillips	R. D. Nuttall Co.
S. P. Rockwell	Metallurgical Engineer
M. P. Rumney	Detroit Steel Products Co.
C. F. W. Rys	Carnegie Steel Co.
R. B. Schenck	Buick Motor Co.
M. H. Schmid	United Alloy Steel Corporation
H. J. Stagg	Halcomb Steel Co.
J. M. Watson	Hupp Motor Car Corporation
H. M. Williams	General Motors Research Corporation
J. H. G. Williams	Billings & Spencer

Iron and Steel Specifications

PART X—EFFECT OF MASS UPON THE PHYSICAL PROPERTIES OF STEEL

(*Proposed General Information*)

The charts of physical properties for S.A.E. Steels, appearing in the S.A.E. HANDBOOK, apply to sections up to 1½-in. diameter or thickness. As the size or the mass of the steel object being heat-treated is increased, the response of the steel to the quenching operation is less marked. Owing to the lack of comprehensive detailed data as to the exact influence of mass upon the physical properties of S.A.E. Steels, the Iron and Steel Division has collected such data as have been available, and a large number of confirmatory tests have been made by representative steel manufacturers and a few steel consumers. The data thus obtained have been prepared in chart form for the information of the members of the Society. Owing to the large amount of work involved in making confirmatory tests, only one steel of each type has been selected, and each of these steels subjected to the following forms of heat-treatments:

(1) Water-quenched and tempered at 1000 deg. fahr.
(2) Oil-quenched and tempered at 1000 deg. fahr.
(3) Water-quenched and tempered at 1200 deg. fahr.
(4) Oil-quenched and tempered at 1200 deg. fahr.

The Iron and Steel Division desires to emphasize that the charts submitted herewith are for purposes of information only and should not be considered as providing absolute values.

It is hoped by the Division that users of large sections will collect and forward to the Division any test data they may have on any S.A.E. Steels in order that these charts may be further verified and extended.

PART IX—GENERAL HEAT-TREATMENTS

SPRING STEEL WIRE

(*Proposed Extension of General Information*)

The Iron and Steel Division recommends that the general information in reference to S.A.E. Steels 1350 and 1360, p. D29a of the S.A.E. HANDBOOK, be extended to include the following sentence:

> For conditions where carbon steels are not suitable, certain alloy steels are available.

It is felt desirable that this sentence be included as a reminder, to users of the specifications, of data already covered elsewhere in the general information in reference to the applications of the various steels.

Chart for S.A.E. Steel 1045

Chemical Composition in Percentage

Carbon	0.40 —0.50
Manganese	0.50 —0.80
Phosphorus	0.045 max.
Sulphur	0.05 max.

Quenched at 1500 deg. fahr. in oil
Drawn at 1000 deg. fahr.

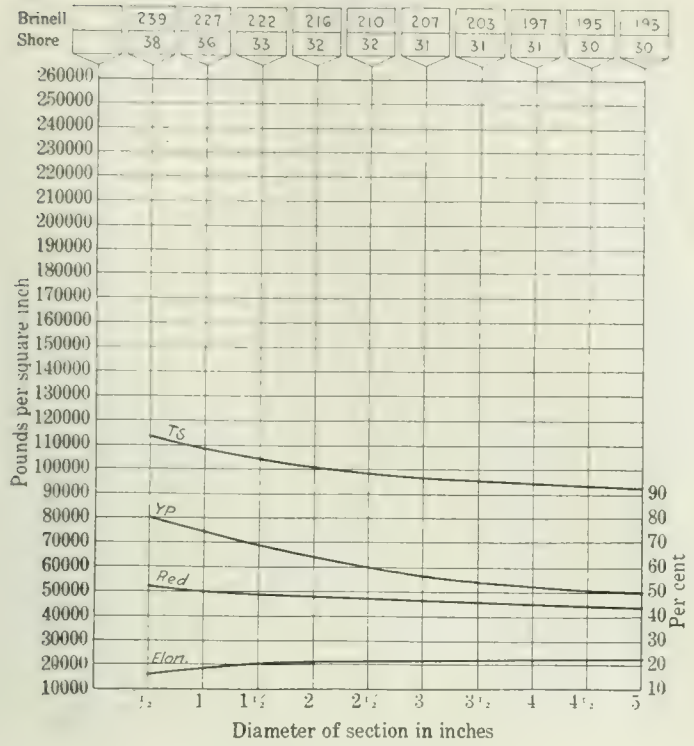

Brinell 239 227 222 216 210 207 203 197 195 193
Shore 38 36 33 32 32 31 31 31 30 30
Pounds per square inch
Per cent
TS
YP
Red.
Elon.
Diameter of section in inches

Chart for S.A.E. Steel 1045

Chemical Composition in Percentage

Carbon	0.40 —0.50
Manganese	0.50 —0.80
Phosphorus	0.045 max.
Sulphur	0.05 max.

Quenched at 1500 deg. fahr. in oil.
Drawn at 1200 deg. fahr.

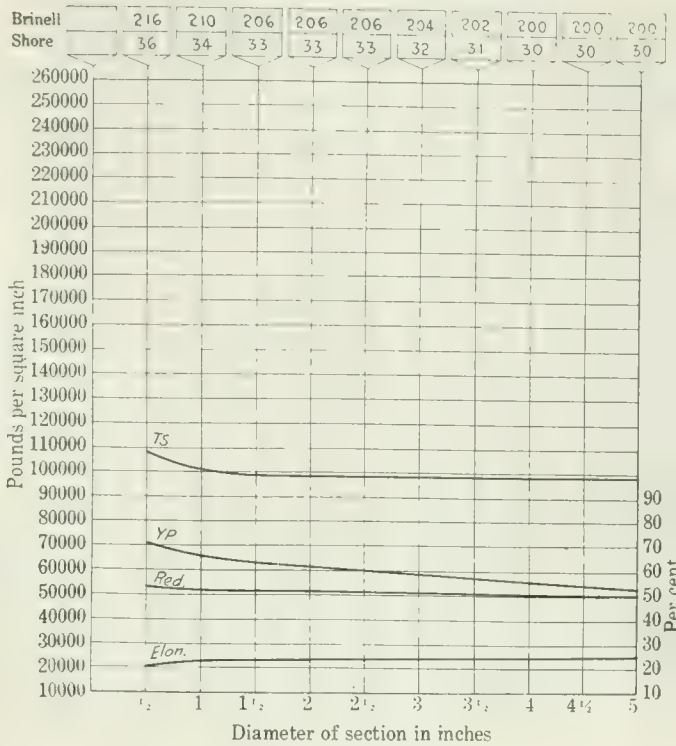

Brinell 216 210 206 206 206 204 202 200 200 200
Shore 36 34 33 33 33 32 31 30 30 30
Pounds per square inch
Per cent
TS
YP
Red.
Elon.
Diameter of section in inches

Chart for S.A.E. Steel 1045

Chemical Composition in Percentage

Carbon	0.40 —0.50
Manganese	0.50 —0.80
Phosphorus	0.045 max.
Sulphur	0.05 max.

Quenched at 1500 deg. fahr. in water.
Drawn at 1000 deg. fahr.

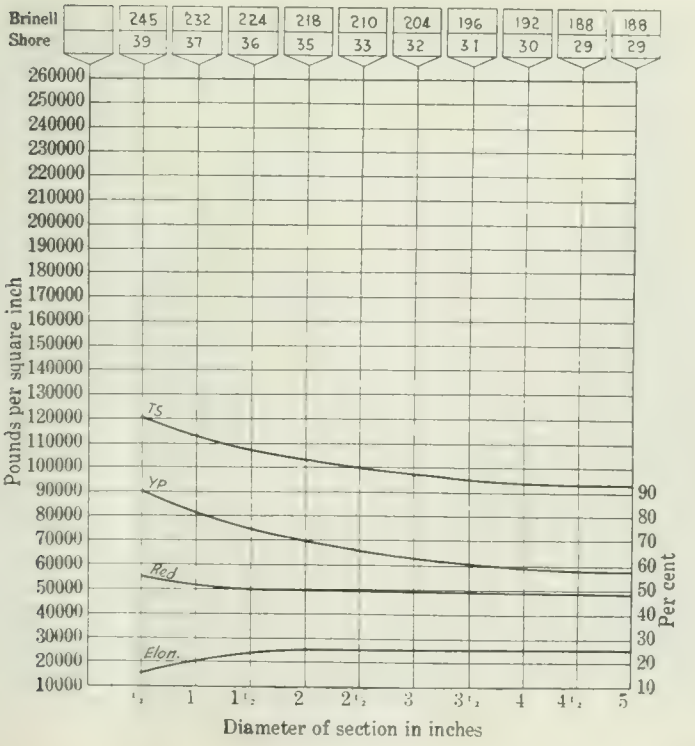

Brinell 245 232 224 218 210 204 196 192 188 188
Shore 39 37 36 35 33 32 31 30 29 29
Pounds per square inch
Per cent
TS
YP
Red.
Elon.
Diameter of section in inches

Chart for S.A.E. Steel 1045

Chemical Composition in Percentage

Carbon	0.40 —0.50
Manganese	0.50 —0.80
Phosphorus	0.045 max.
Sulphur	0.05 max.

Quenched at 1500 deg. in water.
Drawn at 1200 deg. fahr.

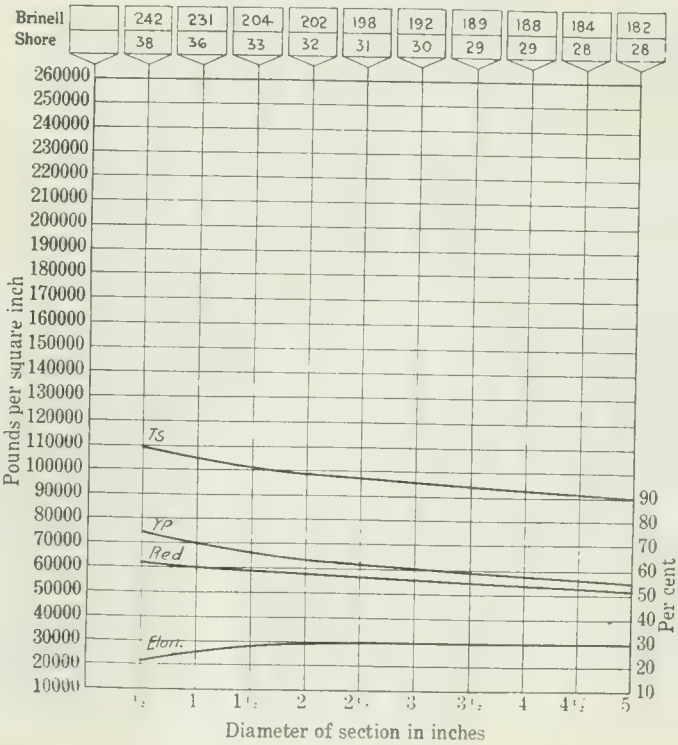

Brinell 242 231 204 202 198 192 189 188 184 182
Shore 38 36 33 32 31 30 29 29 28 28
Pounds per square inch
Per cent
TS
YP
Red.
Elon.
Diameter of section in inches

Chart for S.A.E. Steel 2340

Chemical Composition in Percentage

Carbon	0.35 —0.45
Manganese	0.50 —0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25 —3.75

Normalized at 1625 to 1675 deg. fahr.
Quenched at 1450 deg. fahr. in oil.
Drawn at 1000 deg. fahr.

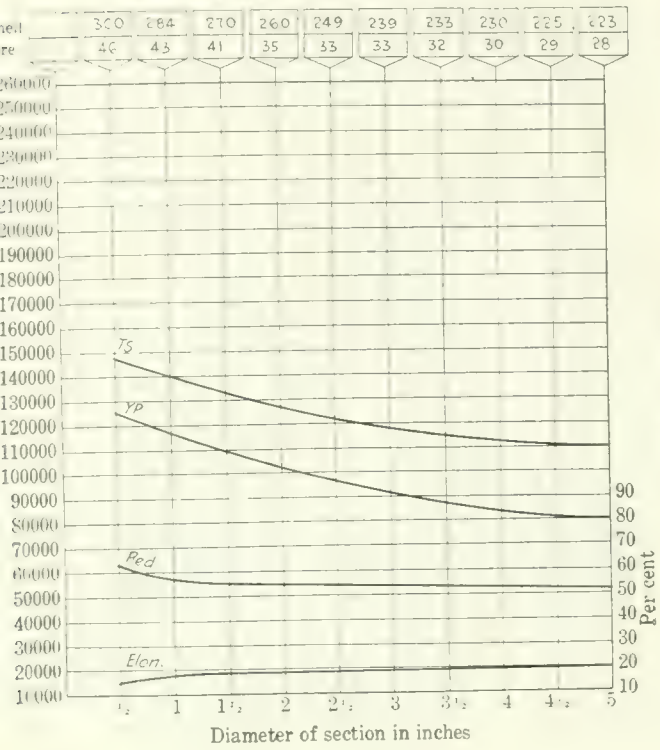


Chart for S.A.E. Steel 2340

Chemical Composition in Percentage

Carbon	0.35 —0.45
Manganese	0.50 —0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25 —3.75

Normalized at 1625 to 1675 deg. fahr.
Quenched at 1450 deg. fahr. in oil.
Drawn at 1200 deg. fahr.

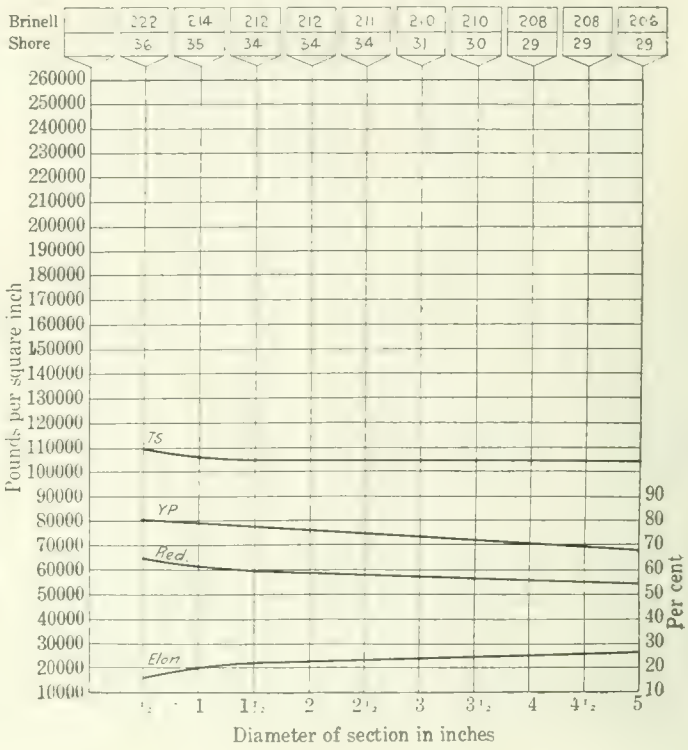

Brinell 222 214 212 212 211 210 210 208 208 206
Shore 36 35 34 34 34 31 30 29 29 29
TS
YP
Red.
Elon
Pounds per square inch
Per cent
Diameter of section in inches

Chart for S.A.E. Steel 2340

Chemical Composition in Percentage

Carbon	0.35 —0.45
Manganese	0.50 —0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25 —3.75

Normalized at 1625 to 1675 deg. fahr.
Quenched at 1450 deg. fahr. in water.
Drawn at 1000 deg. fahr.

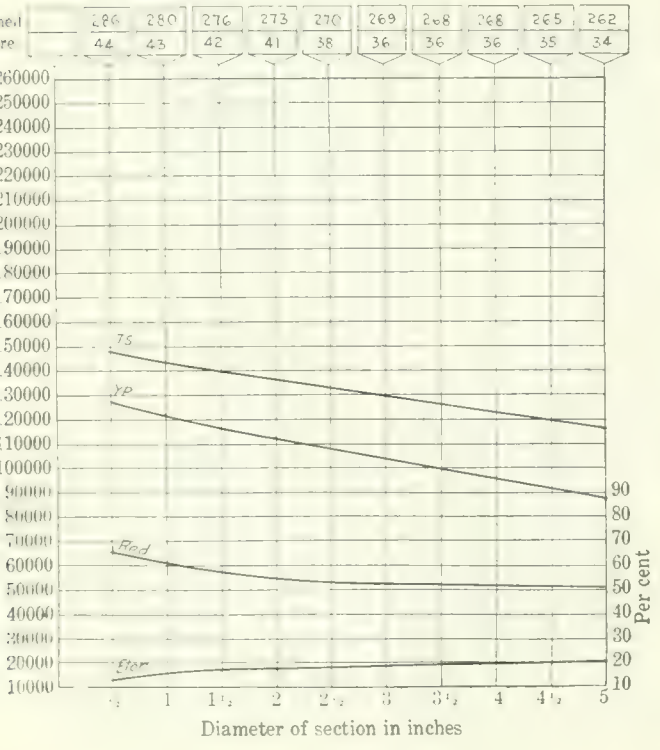

Brinell 286 280 276 273 270 269 268 268 265 262
Shore 44 43 42 41 38 36 36 36 35 34
TS
YP
Red.
Elon
Pounds per square inch
Per cent
Diameter of section in inches

Chart for S.A.E. Steel 2340

Chemical Composition in Percentage

Carbon	0.35 —0.45
Manganese	0.50 —0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	3.25 —3.75

Normalized at 1625 to 1675 deg. fahr.
Quenched at 1450 deg. fahr. in water.
Drawn at 1200 deg. fahr.

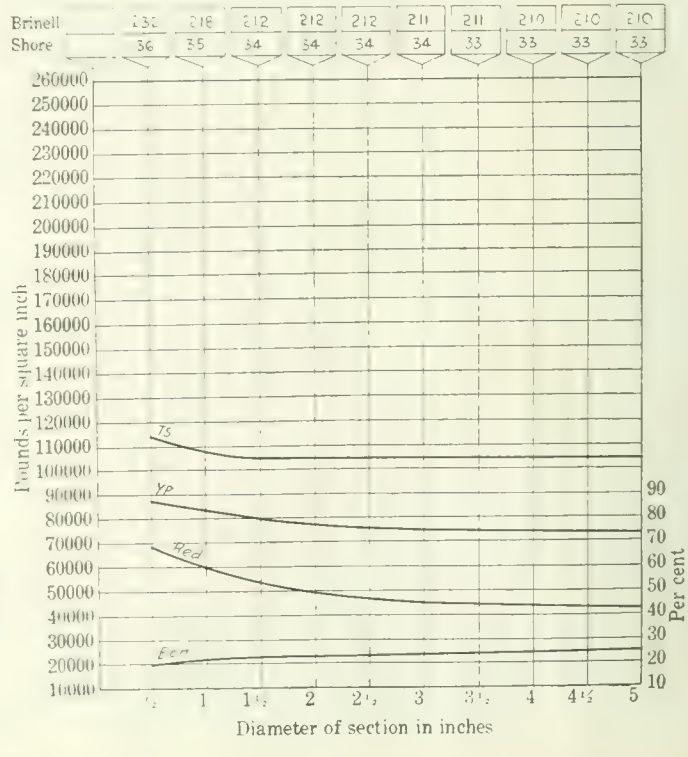

Brinell 236 218 212 212 212 211 211 210 210 210
Shore 36 35 34 34 34 34 33 33 33 33
TS
YP
Red.
Elon
Pounds per square inch
Per cent
Diameter of section in inches

Chart for S.A.E. Steel 3140

Chemical Composition in Percentage

Carbon	0.35 —0.45
Manganese	0.50 —0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	1.00 —1.50
Chromium	0.45 —0.75

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1500 deg. fahr. in oil.
Drawn at 1000 deg. fahr.

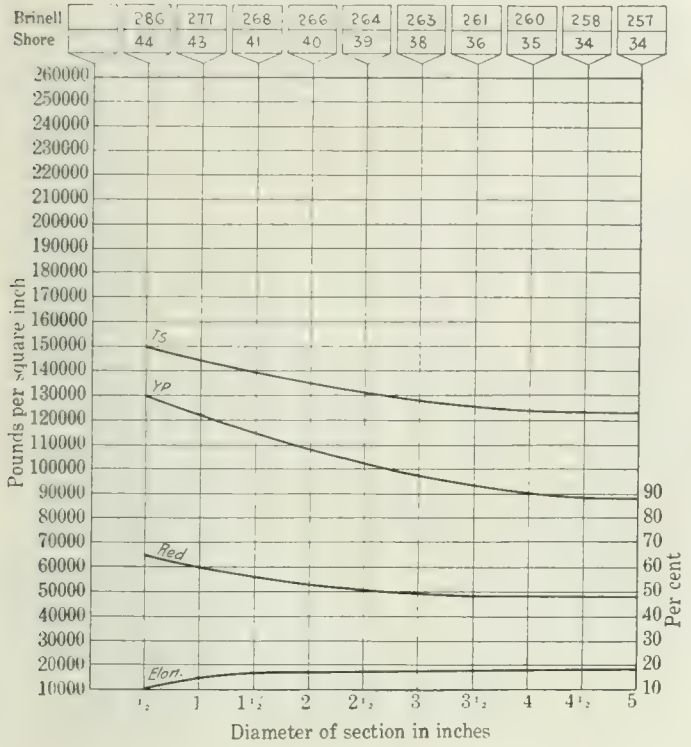


Chart for S.A.E. Steel 3140

Chemical Composition in Percentage

Carbon	0.35 —0.45
Manganese	0.50 —0.80
Phosphorus	0.04 max.
Sulphur	0.045 max.
Nickel	1.00 —1.50
Chromium	0.45 —0.75

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1500 deg. fahr. in oil.
Drawn at 1200 deg. fahr.

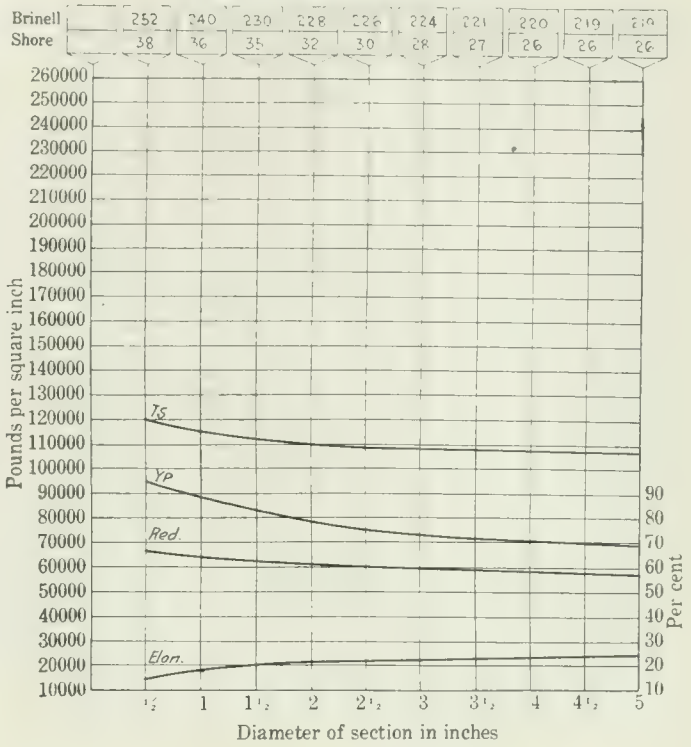


Chart for S.A.E. Steel 3140

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1500 deg. fahr. in water.
Drawn at 1000 deg. fahr.

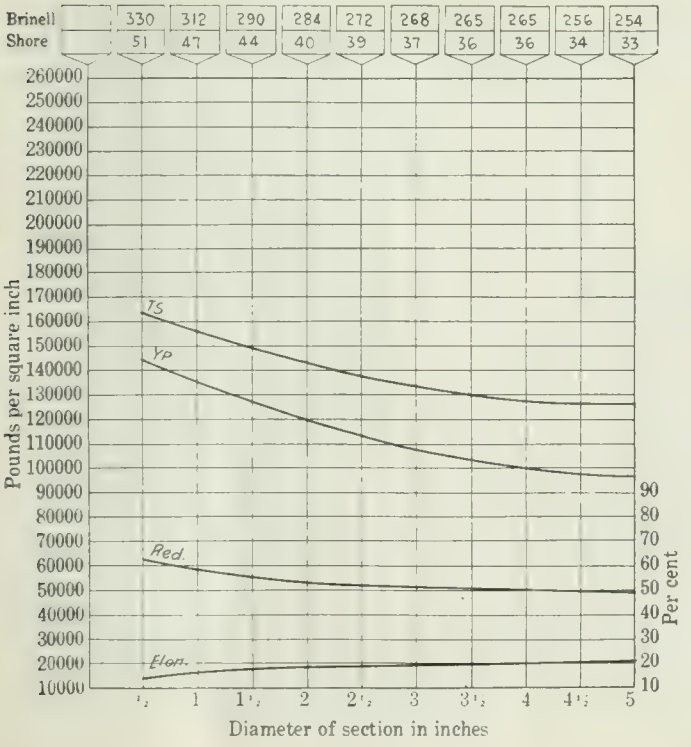


Chart for S.A.E. Steel 3140

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1500 deg. fahr. in water.
Drawn at 1200 deg. fahr.

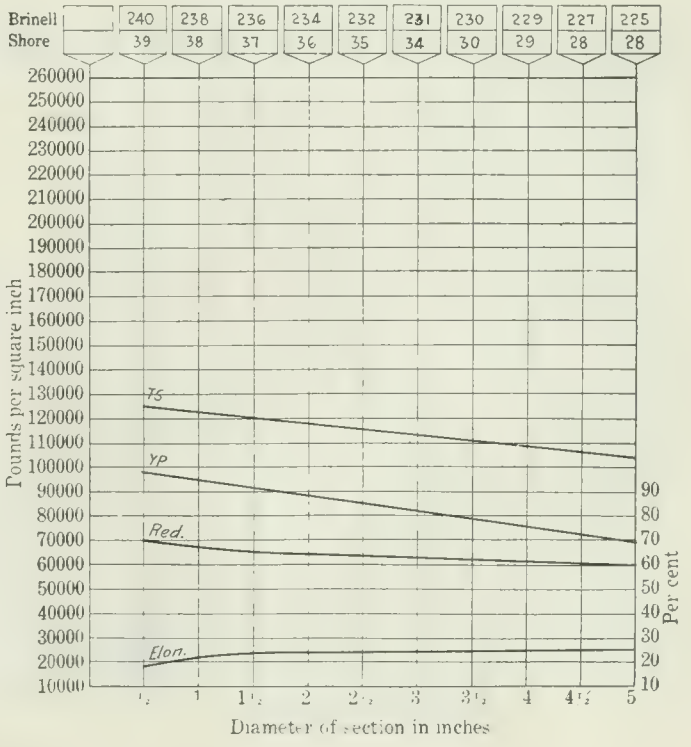


Chart for S.A.E. Steel 3240

Chemical Composition in Percentage

Carbon	0.35—0.45
Manganese	0.30—0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	1.50—2.00
Chromium	0.90—1.25

Normalized at 1625 to 1675 deg. fahr.
Quenched at 1500 deg. fahr. in oil.
Drawn at 1000 deg. fahr.

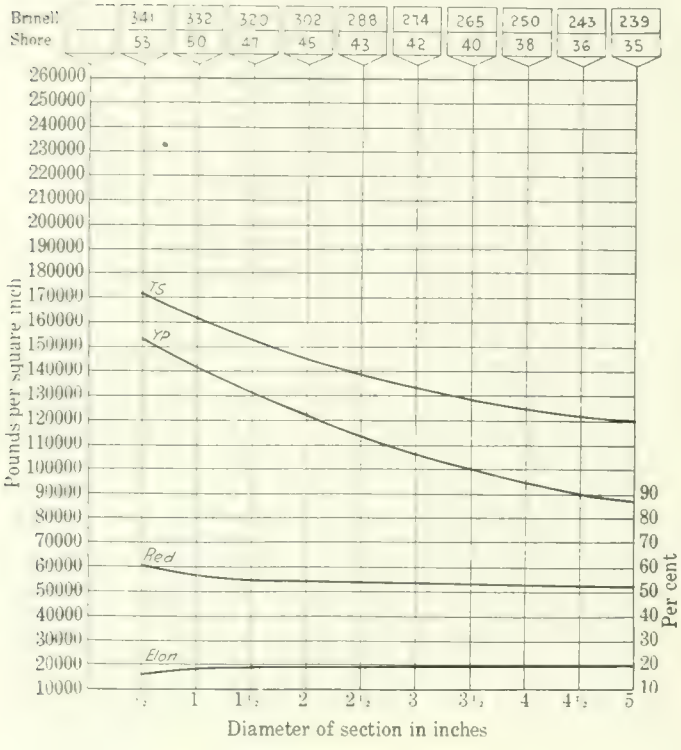

Brinell 341 332 320 302 288 274 265 250 243 239
Shore 53 50 47 45 43 42 40 38 36 35
Pounds per square inch
Per cent
TS
YP
Red
Elon
Diameter of section in inches

Chart for S.A.E. Steel 3240

Chemical Composition in Percentage

Carbon	0.35—0.45
Manganese	0.30—0.60
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	1.50—2.00
Chromium	0.90—1.25

Normalized at 1625 to 1675 deg. fahr.
Quenched at 1500 deg. fahr. in oil.
Drawn at 1200 deg. fahr.

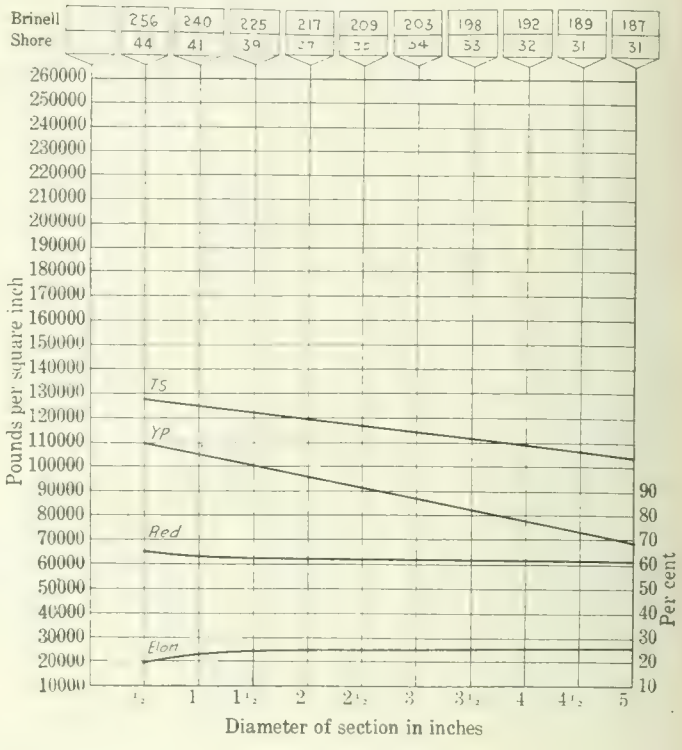

Brinell 256 240 225 217 209 203 198 192 189 187
Shore 44 41 39 37 35 34 33 32 31 31
Pounds per square inch
Per cent
TS
YP
Red
Elon
Diameter of section in inches

Chart for S.A.E. Steel 3240

Normalized at 1625 to 1675 deg. fahr.
Quenched at 1500 deg. fahr. in water.
Drawn at 1000 deg. fahr.

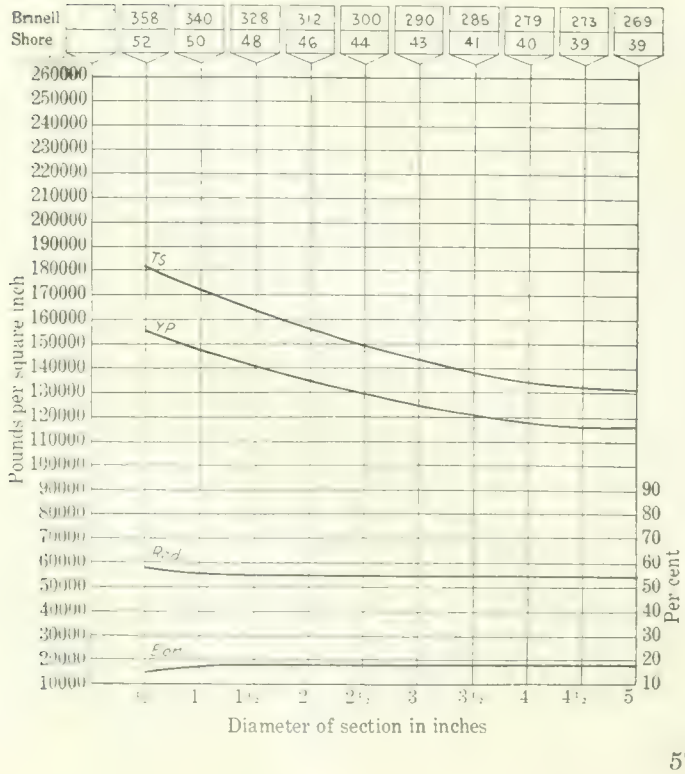

Brinell 358 340 328 312 300 290 285 279 273 269
Shore 52 50 48 46 44 43 41 40 39 39
Pounds per square inch
Per cent
TS
YP
Red
Elon
Diameter of section in inches

Chart for S.A.E. Steel 3240

Normalized at 1625 to 1675 deg. fahr.
Quenched at 1500 deg. fahr. in water.
Drawn at 1200 deg. fahr.

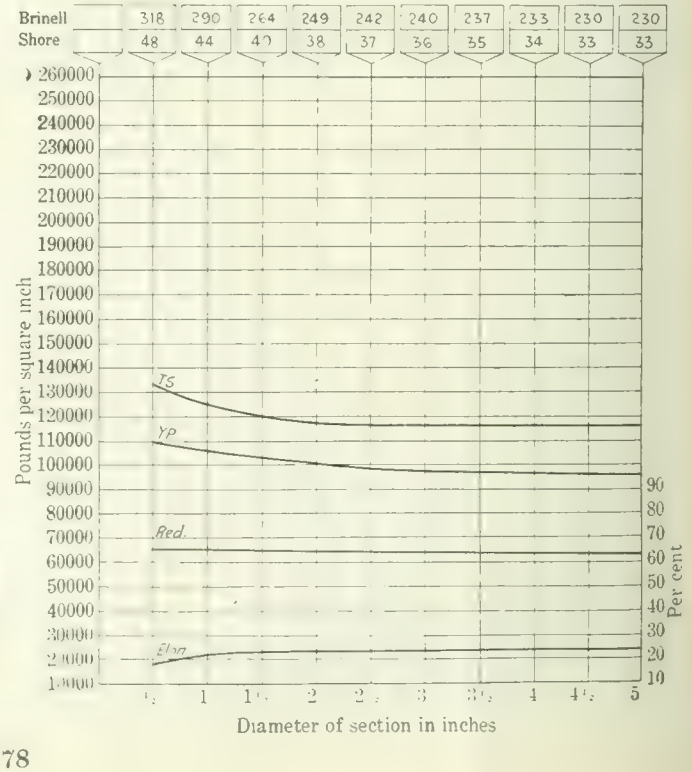

Brinell 318 290 264 249 242 240 237 233 230 230
Shore 48 44 40 38 37 36 35 34 33 33
Pounds per square inch
Per cent
TS
YP
Red.
Elon
Diameter of section in inches

Chart for S.A.E. Steel 3340

Chemical Composition in Percentage

Carbon	0.35—0.45
Manganese	0.50—0.80
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	3.25—3.75
Chromium	1.25—1.75

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1450 deg. fahr. in oil.
Drawn at 1000 deg. fahr.

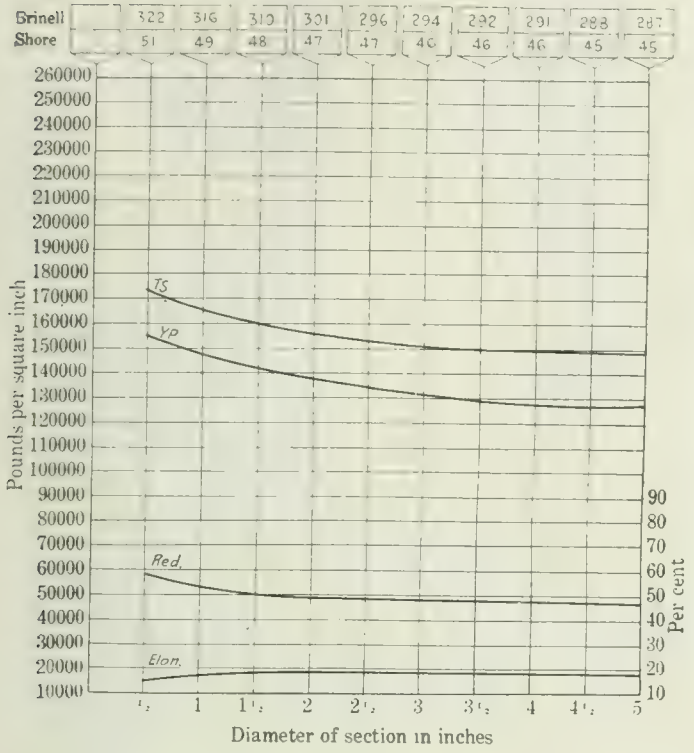

Brinell 322 316 310 301 296 294 292 291 288 287
Shore 51 49 48 47 47 46 46 46 45 45
TS
YP
Red.
Elon.
Pounds per square inch
Per cent
Diameter of section in inches

Chart for S.A.E. Steel 3340

Chemical Composition in Percentage

Carbon	0.35—0.45
Manganese	0.50—0.80
Phosphorus	0.04 max.
Sulphur	0.04 max.
Nickel	3.25—3.75
Chromium	1.25—1.75

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1450 deg. fahr. in oil.
Drawn at 1200 deg. fahr.

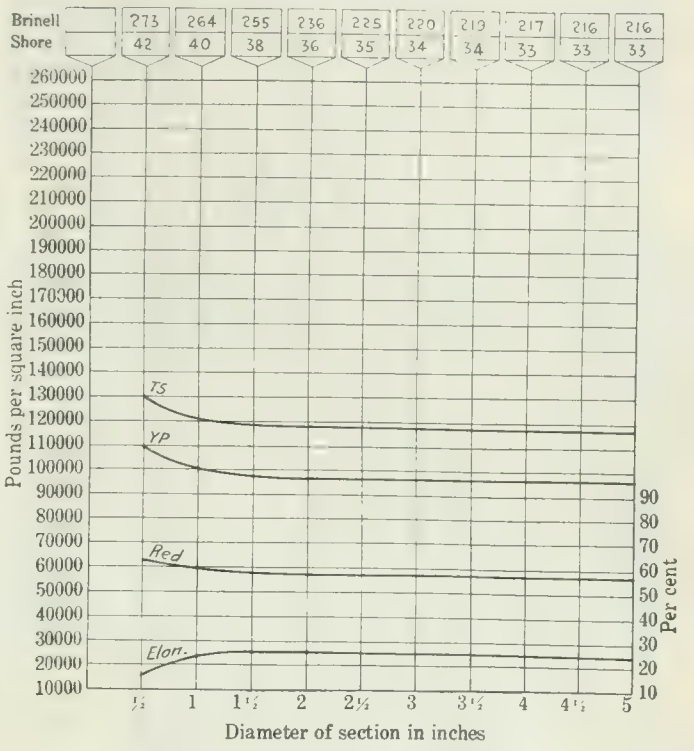

Brinell 273 264 255 236 225 220 219 217 216 216
Shore 42 40 38 36 35 34 34 33 33 33
TS
YP
Red
Elon.
Pounds per square inch
Per cent
Diameter of section in inches

Chart for S.A.E. Steel 3340

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1450 deg. fahr. in water.
Drawn at 1000 deg. fahr.

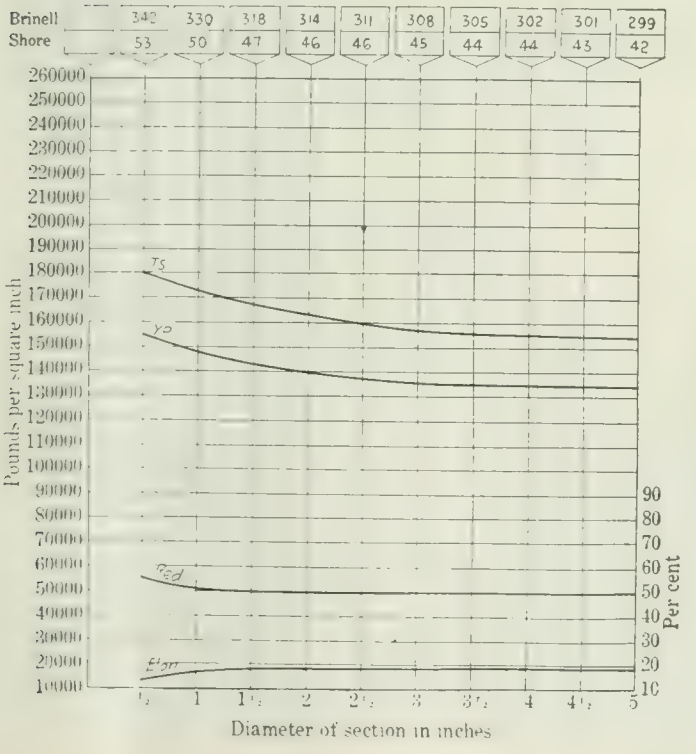

Brinell 342 330 318 314 311 308 305 302 301 299
Shore 53 50 47 46 46 45 44 44 43 42
TS
YP
Red
Elon
Pounds per square inch
Per cent
Diameter of section in inches

Chart for S.A.E. Steel 3340

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1450 deg. fahr. in water.
Drawn at 1200 deg. fahr.

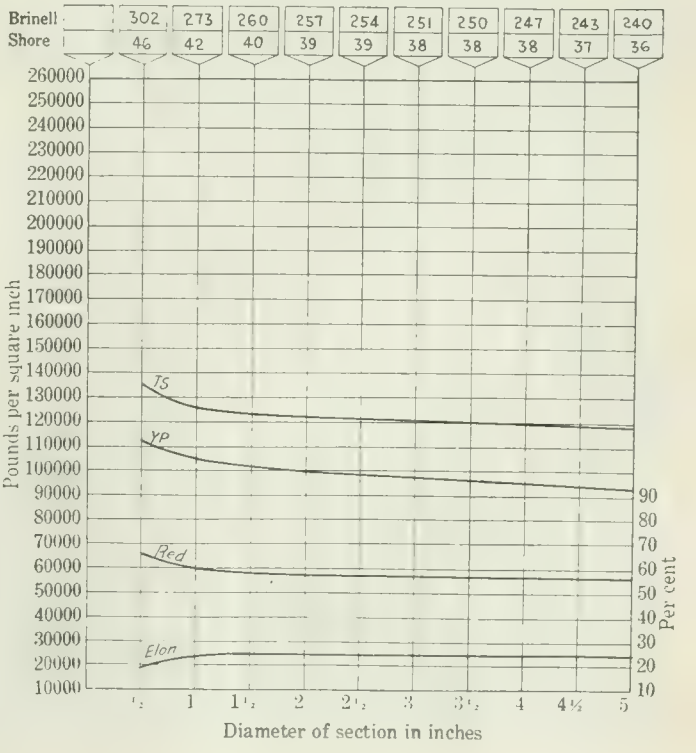

Brinell 302 273 260 257 254 251 250 247 243 240
Shore 46 42 40 39 39 38 38 38 37 36
TS
YP
Red
Elon
Pounds per square inch
Per cent
Diameter of section in inches

CHART FOR S.A.E. STEEL 3435

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.30—0.40
Manganese	0.30—0.60
Nickel	2.75—3.25
Chromium	0.50—0.90

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1450 deg. fahr. in oil.
Drawn at 1000 deg. fahr.

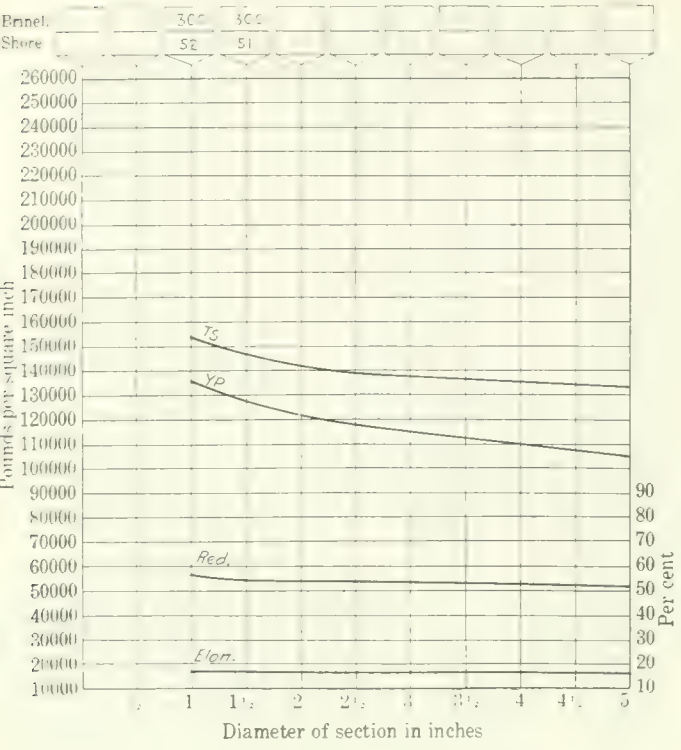
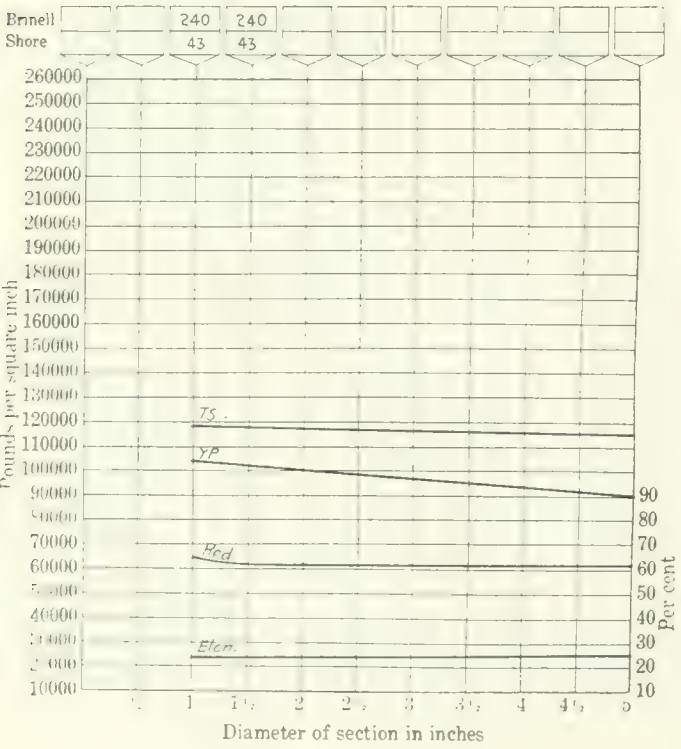


CHART FOR S.A.E. STEEL 3435

CHEMICAL COMPOSITION IN PERCENTAGE

Carbon	0.30—0.40
Manganese	0.30—0.60
Nickel	2.75—3.25
Chromium	0.50—0.90

Normalized at 1600 to 1700 deg. fahr.
Quenched at 1450 deg. fahr. in oil.
Drawn at 1200 deg. fahr.



LIGHTING DIVISION REPORT

Division Personnel

W. A. McKay, *Chairman*	Westinghouse Lamp Co.
C. A. Michel, *Vice-Chairman*	Guide Motor Lamp Mfg. Co.
A. K. Brumbaugh	Autocar Co.
J. T. Caldwell	National Lamp Works
G. P. Doll	Thomas J. Corcoran Lamp Co.
C. E. Godley	Edmunds & Jones Corporation
C. A. B. Halvorson, Jr.	General Electric Co.
J. H. Hunt	General Motors Research Corporation
A. R. Lewellen	Chevrolet Motor Co.
H. H. Magsick	National Lamp Works
W. J. Outcalt	General Motors Corporation
L. C. Porter	Edison Lamp Works
E. S. Preston	Chicago Electric Mfg. Co.
C. D. Ryder	Cincinnati-Victor Co.
A. J. Scaife	White Motor Co.
J. C. Stearns	Culver-Stearns Mfg. Co.
F. W. Todd	Accessories Mfg. Co.
T. I. Walker	Providence Base Works
E. E. Wood, Jr.	Miniature Incandescent Lamp Corporation
Ernest Wooler	Cleveland Automobile Co.

BASES, SOCKETS AND CONNECTORS

(Proposed Revision of S. A. E. Standard)

As a result of recent developments in the manufacture of incandescent lamp bulbs, the Lighting Division recommends that the present S.A.E. Standard for Bases, Sockets and Connectors, p. B4 of the S.A.E. HANDBOOK, be revised by increasing the distance from the contact end of the base, not including the solder, to the open end of the base 1/16 in., thus making the limits for the length of base 0.742 to 0.758 in. instead of 0.679 to 0.695 in.

To prevent the ends of the contacts on double-contact plugs from being too uneven, it is recommended that tolerances of plus and minus 0.005 in. be specified for the distance the contacts extend beyond the end of the plug, which is 1/64 in. As cap breakage has been experienced owing to the lack of a proper shoulder in the bore at the end of the threads, which permits the plugs to screw in beyond the threads and split the cap, it is recommended also that the bore diameter above the threads for single-contact plug caps only be decreased from 17/32 to 7/16 in.

NOMENCLATURE DIVISION REPORT

Division Personnel

H. L. Pope, *Chairman*	Wright Aeronautical Corporation
W. P. Kennedy, *Vice-Chairman*	Kennedy Engineering Corporation
J. B. Bartholomew	Avery Co.
W. F. Borgerd	International Harvester Co.
W. S. Bouton	Hendee Mfg. Co.
W. J. Brandon	Avery Co.
H. R. Cobleigh	National Automobile Chamber of Commerce
H. M. Crane	Consulting Engineer
W. P. Culver	American Auto Parts Co.
A. B. Cumner	Autocar Co.
L. S. Keilholtz	Delco-Light Co.
V. E. McMullen	Hercules Corporation
Leonard Ochtman, Jr.	Joseph VanBlerck Engine Corporation
W. T. Thomas	Ithaca, N. Y.
L. C. Voyles	Nordyke & Marmon Co.
L. M. Woolson	Packard Motor Car Co.

Radiator Nomenclature

(Proposed Revision of S. A. E. Standard)

The Nomenclature Division recommends that Group 1 of Division III of the present S.A.E. Standard for Automobile Nomenclature, p. K1 of the S.A.E. Handbook, be revised in accordance with the accompanying nomenclature proposed for Group 2, Radiator, and Group 3, Radiator Core.

The radiator nomenclature and definitions of the four types of core were formulated by the Radiator Division after considerable study and as a result of several meetings. The report was referred to the Nomenclature Division for coordinating with the existing nomenclature in conformity with the regular nomenclature standardization procedure.

DIVISION III, COOLING SYSTEM

Group 2—Radiator

Shell Type

Radiator core (see Group 3)
Radiator upper tank
Radiator filler-neck
Radiator inlet fitting
Radiator tie-rod fitting
Radiator overflow tube
Radiator lower tank
Radiator outlet fitting
Radiator drain-cock
Radiator anchor stud or bolt
Radiator anchor stud or bolt plate
Radiator side bolting-member
Radiator shell
Radiator supports
Radiator hinge-rod fitting
Radiator hood-ledge liner

Cast Type

Radiator core (see Group 3)
Radiator upper tank
Radiator filler-cap
Radiator inlet fitting
Radiator tie-rod fitting
Radiator overflow tube
Radiator outlet fitting
Radiator drain-cock
Radiator anchor stud or bolt
Radiator anchor stud or bolt plate
Radiator sides
Radiator clamping strips
Radiator header gasket
Radiator inlet gasket
Radiator outlet gasket
Radiator hinge-rod fitting
Radiator hood-ledge liner

Group 3—Radiator Core

Individual Fin and Tube Core.—An assembly of fluid tubes of any cross-sectional form to each of which are attached gills or fins of circular, square or other shape, each tube and its fin or fins forming a separate unit.

Continuous Fin and Tube Core.—An assembly of fluid tubes of any cross-sectional form, the tubes being joined together by radiating fins or plates common to all the tubes.

Ribbon Cellular Core.—A number of fluid passages formed by joining metal ribbons at the edges, the fluid passage walls usually being crimped and grouped to form a cellular structure. Parts of the cellular structure may be formed by flat or crimped ribbon which is not a part of the water passage.

Air Tube Cellular Core.—An assembly of air tubes nested in such a way as to form fluid passages between the tubes, the passages being sealed at the ends of the tubes. In this type the fluid may flow transversely as well as vertically around the tubes.

Parts and Fittings Division Report

Division Personnel

W. C. Keys, *Chairman*	Gabriel Snubber Sales & Service Co.
C. R. Alling	Underwriters' Laboratories
Clarence Carson	Dodge Bros.
H. B. Garman	Garman Mfg. Co.
H. S. Jandus	C. G. Spring Co.
W. J. Outcalt	General Motors Corporation
F. W. Slack	Peerless Motor Car Co.
C. W. Spicer	Spicer Mfg. Corporation
E. W. Weaver	Weaver & Kemble Co.
F. G. Whittington	Stewart-Warner Speedometer Co.

Brake-Lining

(Proposed Revision of S.A.E. Standard)

The Parts and Fittings Division recommends that the present S.A.E. Standard for Brake-Lining, p. C55 of the S.A.E. Handbook, be revised by the addition of the 1/4 x 4 and the 5/16 x 5-in. sizes and by the elimination of the following sizes:

3/32 x 2 1/4	1/8 x 2 3/4
1/4 x 1 3/4	3/8 x 2 3/4
1/4 x 2 1/4	3/8 x 3
1/4 x 2 3/4	3/8 x 3 1/4
5/16 x 2 1/4	3/8 x 4
5/16 x 2 1/2	3/8 x 4 1/2

The standard revised in compliance with the recommendation of the Division is given in Table 14.

It is considered that the 18 sizes of brake lining in the revised standard are required to cover the necessary range of applications. The 5/32 x 1 1/8-in. size is included as it is used extensively for motorcycles. The standard is, of course, intended for adoption in future production as changes in design permit.

The Subdivision, of which Clarence Carson, of Dodge Bros., is chairman, is also working on the standardization of brake-lining tests, much time and money having been expended in the development of several testing-machines that have been tried out by the brake-lining manufacturers and the Bureau of Standards. The work has not progressed to such a point, however, that a report can be made at this time.

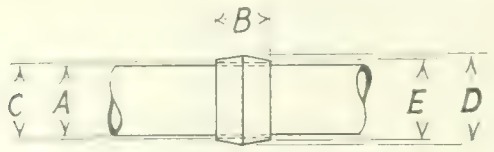
TABLE 14—PROPOSED REVISED STANDARD FOR BRAKE-LINING SIZES

Width, In.	Thickness, In.			
±1/16	3/32	1/16	1/4	5/16
1 1/8	*			
1 1/4	*			
1 1/2	*	*		
1 3/4	*	*		
2	*	*	*	
2 1/4		*		
2 1/2		*	*	
3			*	*
3 1/2				*
4			*	*
5				*
Thickness Tolerances	+0.000 —0.020	+0.000 —0.020	+0.000 — 1/2	+0.000 — 1/2

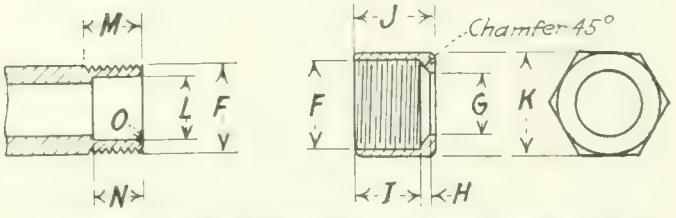
Fuel and Lubrication Pipe Fittings—Compression Type

(Proposed S.A.E. Recommended Practice)

The Parts and Fittings Division recommends for adoption as S.A.E. Recommended Practice the accompanying compression-type fuel and lubrication pipe fittings. The dimensions proposed were prepared by a Subdivision consisting of W. H. Hollister, of the Imperial Brass Co., and

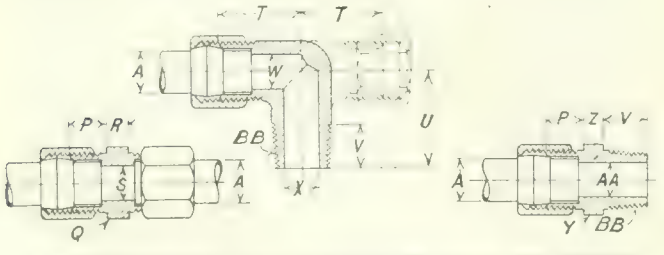


Tubing Diameter A	B	C Max	C Min.	D	E
1/8	3/16	0.132	0.128	3/16	0.140
3/16	3/32	0.195	0.191	17/64	0.203
1/4	1/4	0.257	0 253	11/32	0.266
5/16	9/32	0.320	0.316	13/32	0.329
3/8	5/16	0.383	0.379	15/32	0.392
1/2	7/8	0.509	0.505	19/32	0 518



Tubing Diameter A	F*	G Max	G Min.	H	I	J	K	L ±0.002	M Min.	N	Radius O
1/8	24	0.134	0 130	3/64	1/4	11/32	3/8	0.134	1/4	3/16	3/64
3/16	24	0 197	0 193	1/16	5/16	1/2	1/2	0.199	5/16	3/32	1/16
1/4	24	0 260	0 256	1/16	11/64	11/32	1/2	0.260	5/16	1/4	3/16
5/16	24	0 323	0.319	1/16	21/64	1/2	5/8	0 323	1/2	3/32	1/8
3/8	24	0 386	0.382	1/16	3/8	13/32	3/4	0.386	3/4	1/16	1/16
1/2	20	0.512	0 508	3/64	1/2	3/4	11/16	0.512	7/16	1/8	3/64

*U. S. Standard Form.



Tubing Diameter A	P	Q Hexagon Diameter	R	S	T	U	V	W	X	Y Hexagon Diameter	Z	AA	BB†
1/8	1/4	1/4	1/8	3/32	1/8	11/16	1/8	3/32	3/16	7/16	3/32	1/8	1/8
3/16	5/32	1/4	5/32	1/8	11/16	11/32	1/8	1/8	3/16	7/16	3/16	1/8	1/8
1/4	1/8	1/2	1/16	1/8	3/4	1/4	1/8	3/16	3/16	7/16	3/16	1/8	1/8
5/16	11/64	5/16	1/16	1/8	13/16	7/16	1/8	7/32	1/4	1/2	1/16	3/32	1/8
3/8	1/4	5/16	7/32	5/16	1	1/2	1/8	5/16	5/16	9/16	3/32	5/16	1/8
1/2	1/4	3/8	1/4	11/32	11/16	1/2	1/8	11/32	11/32	11/16	7/32	1/4	1/8

†American Standard (Briggs) Pipe Thread

W. J. Outcalt, of the General Motors Corporation. Although the threads specified in the recommendation are S.A.E. Standard only for the 1/8 and 3/16-in. sizes, the threads recommended were selected many years ago because the coarser threads, then standard, were unsatisfactory when used in applications subject to severe vibration. Consequently any changes made in the pitches at the present time would affect the entire output of practically all of the compression-type fitting manufacturers as the dimensions proposed are practically standard at the present time.

Rod-End Pins

(Proposed Revision of S.A.E. Standard)

Since the present S.A.E. Standard for Rod-End Pins, p. C10 of the S.A.E. HANDBOOK, was adopted by the Society in January, 1915, production developments have made possible the manufacture of rod-end pins by upsetting the heads, which require slightly greater diameter tolerances.

The Parts and Fittings Division therefore recommends that the present S.A.E. Standard for Rod-End Pins be revised to specify tolerances of minus 0.002 to minus 0.007 in. for nominal diameters 3/16 to 7/16 in. inclusive and minus 0.004 to minus 0.009 for nominal diameters from 1/2 to 1 in. inclusive.

Cotter-Pins

(Proposed Revision of S.A.E. Standard)

The Parts and Fittings Division recommends that the present S.A.E. Standard for Cotter-Pins, p C7 of the S.A.E. HANDBOOK, be revised to conform to the dimensions given in Table 15. The present standard specifies that cotter-pin holes shall be drilled oversize on the basis that cotter-pins are manufactured in accordance with the nominal cotter-pin sizes. It has become general practice to produce cotter-pins smaller than the nominal size, however, and consequently the cotter-pin holes should be drilled to size.

The Division also takes this opportunity to omit all cotter-pin diameters expressed in sixty-fourths of an inch and to add the 5/32, 3/16, 7/32, 1/4 and 5/16-in. nominal sizes. In submitting this recommendation, the Division contemplates that in case the report is approved, all other S.A.E. Standards and Recommended Practices specifying cotter-pins will be brought into agreement with this proposed revision.

TABLE 15—PROPOSED STANDARD COTTER-PIN DIMENSIONS

Length, In. (L)	D—Nominal Trade Diameters, In. 1/16	5/32	1/8	3/32	1/16	5/32	1/4	5/16
5/16	*							
7/16	*							
1/2	*	*						
5/8	*	*						
3/4	*	*						
7/8	*	*	*					
1		*	*					
1 1/8		*	*					
1 1/4			*	*				
1 3/8			*	*				
1 1/2			*	*				
1 5/8			*	*	*			
1 3/4			*	*	*			
2				*	*	*		
2 1/4				*	*	*	*	
2 1/2					*	*	*	*
2 3/4						*	*	*
3						*	*	*

Actual wire diameter limits, in.:

0.061	0.090	0.122	0.150	0.176	0.207	0.225	0.280
0.058	0.086	0.118	0.146	0.172	0.202	0.220	0.275

The Washburn and Morn steel wire gage is usually used for specifying cotter-pin wire sizes.

TABLE 16—PROPOSED FELT SPECIFICATIONS

S.A.E. Specification No.	Trade Classification	Wool, Per Cent	Ash Per Cent, Max.	Color	Thickness Tolerance, Plus or Minus, Per Cent
F1	Back Check	100	1.00	White	10
F2	Back Check	100	1.00	Any Color	10
F3	Back Check	95–100	1.25	Any Color	10
F10	Firm Pad	100	1.00	White	10
F11	Firm Pad	100	1.25	Grey	10
F12	Firm Pad	90–95	1.25	Grey	10
F13	Firm Pad	80–85	1.25	Grey	10
F15	Firm Pad	60–65	1.50	Grey	10
F26	Soft Pad	50–55	1.50	Grey	10
F30	Medium Sheet	100	1.25	White	5
F50	Colored Shoe Upper	100	1.25	All Colors[5]	10
F51	Shoe Upper	70	1.25	Grey and Black	15
F60	Asbestos	50[4]	5.00	Grey	15

[3] This a trade term and does not refer to universal asbestos.
[4] 50 per cent reworked wool and 50 per cent wool substitutes.
[5] Except gray and black.

Felt Specifications

(Proposed S. A. E. Recommended Practice)

In the face of the wide difference of opinion as to the possibility of formulating practical specifications for felt, the Parts and Fittings Division appointed in 1920 a Subdivision on Felt which undertook the task of formulating felt specifications that would be of real assistance to engineers and purchasing agents.

A preliminary report was submitted by the Subdivision, of which H. W. Jarrow, of the American Felt Co., was chairman, and was circularized among manufacturers and users for comments, which were used as the basis in formulating the felt specifications. These were approved after being modified somewhat by the Parts and Fittings Division, and are submitted herewith for approval as S.A.E. Recommended Practice.

The result of the circular letter on felt specifications brought out the fact that the specifications were considered to be of real value to the engineering fraternity in that they establish definite specifications for a product that has hitherto been purchased by sample only.

The specifications were printed in the May issue of THE JOURNAL under the heading "Tentative Standardization Work" but no adverse comments were received from the members of the Society.

The Subdivision made an effort to develop some satisfactory method for measuring the thickness of felt but without success. The purchaser is protected, however, as the weight of the felt is definitely given in the specification.

To determine the percentage of wool, the following method abstracted from Sadtler's Industrial Organic Chemistry should be used

Boil a 2-gram sample of the material to be tested in 60 to 80 cc. of sodium-hydroxide solution of 1.02 specific gravity for 15 min., using a reflux condenser. Wash the residue with distilled water until the sodium-hydroxide and the saponified wool are removed, then press out the water, dry in air and weigh.

$$\text{Per Cent Wool} = 100\ (W - 1.05\ w) \div W$$

where

W = the weight of the original sample
w = the weight of the residue

Since hair and other animal fibers similar to wool will be saponified and included in the resulting percentage, a microscopic examination should be made of the original sample.

All of the above grades of felt shall be free from starch, glue or other similar materials.

All weights shall be based on the thickness of the felt as ordered and no correction in weight shall be made for variations in the thickness of the material received.

The appearance, hardness, and oil-absorption qualities shall be in accordance with a sample of felt approved by the engineering department and retained as a standard by the purchasing and inspection departments.

General Information.—Back check and firm pad felts are recommended for use in washers, bushings, oiling wicks, door bumpers and similar parts.

Soft pad felt is intended for chassis strips. Medium

TABLE 17—THICKNESS AND WEIGHT OF PROPOSED STANDARD FELTS

S. A. E. Specification No.	Weight of Felt, Lb. per Sq. Yd. per 36-in. Width Allowable Tolerance, Plus or Minus 10 Per Cent									
	Felt Thickness, In.									
	1/8	3/16	1/4	5/16	3/8	1/2	3/4	1	1 1/2	2
F1	2.00	3.00	3.95	5 10	6.00	8.20	....	....	....	....
F2	2.00	3.00	3.95	5.10	6.00	8.20	....	....	....	....
F3	2.00	3.00	3.95	5.10	6.00	8.20	....	....	....	....
F10	1.50	1.75	2.25	2.75	3.25	4.25	....	....	....	....
F11	1.50	1.75	2.25	2.75	3.25	4.25	....	....	....	....
F12	1.50	1.75	2.25	2.75	3.25	4.25	....	....	....	....
F13	1.50	1.75	2.25	2.75	3.25	4.25	....	....	....	....
F15	1.50	1.75	2.25	2.75	3.25	4.25	....	....	....	....
F26	1.10	1.50	1.90	....	....	....	....	....	....	....
F30	....	....	5.00	....	7.50	10.00	17.50	20.00	30.00	40 00
F50[b]	....	....	....	....	....	....	....	....	....	....
F51[c]	....	....	....	....	....	....	....	....	....	....
F60	....	....	1.50	....	2.25	3.00	4 50	6.00	....	....

[b] Specification No. F50 shall weigh 20 oz. per yd. 60. in. wide when 0.050 in. thick; 22 oz. when 0.055 in. thick; 24 oz. when 0.060 in. thick; 26 oz. when 0.065 in. thick; 28 oz. when 0.070 in. thick; 30 oz. when 0.075 in. thick; 32 oz. when 0.080 in. thick and 34 oz. when 0.085 in. thick.
[c] Specification No. F51 shall weigh 12 oz. per yd. 60 in. wide when 1.32 in. thick; 18 oz. when 3 64 in. thick; 24 oz. when 1 16 in. thick and 30 oz. when 5/64 in. thick.

sheet felt is intended for use where a felt harder than back check felt is required.

Colored shoe upper felt is intended for use for ball and roller bearing oil-retainer washers and for use where an accurate, thin, smooth, high-grade felt is desired.

Shoe upper felt is intended for use where a felt thinner than back check or pad felt is required and where the higher quality of colored shoe upper felt is not required.

Asbestos felt is intended for such applications as soft top padding or cushions.

License-Plates and Brackets

(Proposed Cancellation of S.A.E. Standard)

The Parts and Fittings Division recommends that the present S.A.E. Standard for License-Plates and Brackets, p. C56 of the S.A.E. HANDBOOK, be cancelled as it has become obsolete through development in license-plate design since the standard was approved in 1916.

The Division is considering the advisability of recommending standard dimensions for the location of the slot in the license-plate bracket which will permit the greatest possible variation of the position of the holes in the license-plates in line with the specifications incorporated in the Massachusetts State law.

Taper Fittings with Plain or Slotted Nuts

(Proposed Extension of S.A.E. Standard)

As the Motorboat Division desired to extend the present standard for motorboat couplings to include the sizes most generally used in present practice, the Parts and Fittings Division was asked to supply the dimensions for taper fittings for the 1⅝, 1⅞ and 3¼-in. nominal shaft-diameters, which are not included in the present S.A.E. Standard for Taper Fittings with Plain or Slotted Nuts.

The dimensions given in the accompanying table were submitted by C. W. Spicer, who formulated the original taper and spline-fitting standards, and were approved by the Division and transmitted to the Motorboat Division for use in the motorboat coupling standards. The Parts and Fittings Division therefore recommends that the dimensions given in Table 18 be adopted as an extension of the present S.A.E. Standard for Taper Fittings with Plain or Slotted Nuts, p. C14 of the S.A.E. HANDBOOK.

TABLE 18—DIMENSIONS FOR TAPER FITTINGS WITH PLAIN OR SLOTTED NUTS

Nom. Diam.	Shaft D_1		Diam. of Hole D_2		L_6	L_7	L_8	L_9	D_3	Threads, per In.	T	T_1
	Max.	Min.	Max.	Min.								
1⅝	1.626	1.624	1.622	1.620	2½	2¼	2¼	1⅛	1¼	18		
1⅞	1.876	1.874	1.872	1.870			2½		1¼	18		
3¼	3.252	3.248	3.245	3.242	3½	4¼	4¼	1¾	2	16	1	

Nom. Diam.	Width Across Flats of Nut	B		h		Square Key		C
		Max.	Min.	Max	Min.	Max	Min	
1⅝	2⅜	0.4375	0.4365	0.2242	0.2217	0.4390	0.4380	
1⅞	2¾	0.4375	0.4365	0.2242	0.2217	0.4390	0.4380	
3¼	4¾	0.7500	0.7485	0.3900	0.3850	0.7520	0.7505	

For reference letters, see p. C14 of the S.A.E. HANDBOOK.

TRUCK DIVISION REPORT

Division Personnel

A. J. Scaife, *Chairman*	White Motor Co.
J. R. Coleman, *Vice-Chairman*	Selden Truck Corporation
A. K. Brumbaugh	Autocar Co.
F. W. Davis	Consulting Engineer
H. E. Derr	International Harvester Co.
J. C. Haggart, Jr.	Republic Motor Truck Co.
A. W. S. Herrington	Quartermaster Corps
M. C. Horine	International Motor Co.
E. A. Kingsbury	Sanford Motor Truck Co.
H. B. Knap	Packard Motor Car Co.
J. A. Kraus	Garford Motor Truck Co.
W. M. Petty	Service Motor Truck Co.
F. A. Whitten	General Motors Truck Co.

Motor-Truck Cabs

(Proposed S.A.E. Recommended Practice)

In 1921 the Truck Division was asked to consider the possibility of standardizing motor-truck cabs as it was recognized that conditions in the industry made it impossible for cab manufacturers to use quantity-production methods, the general practice being to sell the chassis without cabs, these being obtained by the chassis purchasers at additional expense and loss of time. As the Truck Division had recommended standard motor-truck body-installation dimensions, which had been adopted by the Society, it was considered desirable to continue this work to establish the necessary dimensions for obtaining interchangeabilities of cabs.

Information was therefore obtained from the motor-truck builders as to their cab-mounting dimensions, the consensus of opinion of the companies being that cab standardization was desirable. It was recognized, however, that no recommendation of the Division should limit truck design in any way.

As a result of the information obtained, a tentative recommendation was submitted for general comment by the Truck Division in September, 1922. As the comments received indicated further revisions were desirable, the recommendation was further revised and again submitted for comment in October of the same year. At the January Society Meeting in 1923 the Division reviewed the comments that had been received and although it was recognized that the recommendation was fundamentally right, it was considered that final action should not be taken on the proposal until the cab manufacturers and users had had an opportunity to discuss the recommendation at an open meeting. Such a meeting was held in Detroit in March, 1923, the tentative recommendation having been circularized again in the meantime, and the comments being discussed in detail at the meeting.

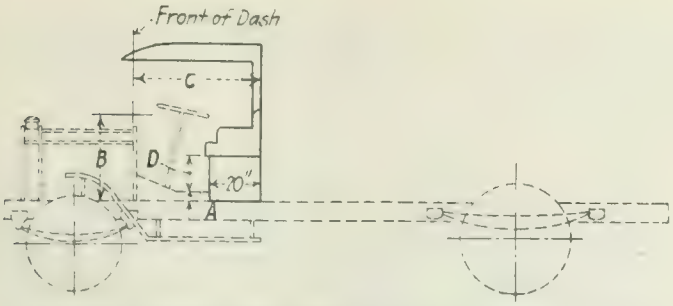
As it was possible to obtain definite agreement at this meeting, the Truck Division recommends for adoption as S.A.E. Recommended Practice the accompanying cab dimensions and also recommends that the accompanying paragraphs be included with the recommendation as "General Information Only." At the meeting in March the original recommendation was extended to include cabs intended for "speed-wagons," as it was felt that practice was sufficiently established to specify definitely mounting dimensions for such cabs.

Subsequent to the last meeting, the recommendation as submitted herewith was referred to motor-truck and motor-truck cab manufacturers for final comment. The replies received were favorable to the present recommendation and the Division feels confident that in submitting the accompanying proposal it is meeting the wishes of the entire motor-truck industry.

GENERAL INFORMATION

The filler-pipe should be of the flush type and located at least 6 in. from the center of the fuel tank.

When it is desired to provide a space under the seat for the storage-battery and the tool-boxes, a square fuel-tank should be used.



Truck Capacity, Tons	A	B[1] Max.	C	D Max.	D Min.
1½ and Under	2	28	46	13	10
1½ and Over	3½	36	46	15½	13½

[1] Dimension *B* is from the top of the chassis frame to the top of the highest dash that can be accommodated.

As it is difficult to design practical cabs when extremely wide dashes are used, the maximum dash-width should be 44 in. for all trucks of 1½ tons capacity or larger. For trucks of smaller capacity, the maximum dash-width should be 37 in.

STATIONARY-ENGINE DIVISION REPORT

Division Personnel

L. F. Burger, *Chairman*	International Harvester Co.
C. B. Segner, *Vice-Chairman*	Domestic Engine & Pump Co.
H. G. Holmes	Novo Engine Co.
V. E. McMullen	Hercules Corporation
T. C. Menges	Associated Manufacturers Co.
I. J. Nelson	Nelson Bros.
O. A. Powell	Cushman Motor Works
L. W. Witry	Waterloo Gasoline Engine Co.

STATIONARY-ENGINE CRANKSHAFTS

(Proposed Cancellation of S.A.E. Recommended Practice)

In April, 1921, the Stationary-Engine Division approved a series of crankshaft and crank-pin diameters which was adopted by the Society in July, 1921, and printed on p. A29 of the S.A.E. HANDBOOK. As a result of several votes cast against this recommendation by the Society members, the Council requested the Division to reconsider it. As subsequent consideration indicated that there is too great a variation of engine sizes and designs to permit practical standardization of crankshafts and crank-pin diameters, the Stationary-Engine Division recommends that the original recommendation of the Division be cancelled.

STATIONARY-ENGINE BELT-SPEEDS

(Proposed S.A.E. Recommended Practice)

In 1921 the Stationary-Engine Division recommended the adoption as S.A.E. Recommended Practice of a series of stationary-engine belt-speeds. This commendation was, however, criticized adversely by members of the Society and referred back to the Division by the Standards Committee for further study.

This subject has received further consideration by the members of the Stationary-Engine Division as the result of which the accompanying table of belt speeds is recommended for adoption as S.A.E. Recommended Practice. It is felt that the recommendation will provide information to engine builders as well as power-driven equipment manufacturers which should be used in designing new apparatus to obtain the proper operation of farm equipment.

TABLE 19—STATIONARY-ENGINE BELT-SPEEDS

Rated Engine Power, Hp.	Belt Speed, Ft. per Min.
1½	600
2	750
3	950
4	1,125
5	1,275
6	1,400
7	1,500
8	1,600
9	1,650
10	1,700
12	1,800
15	1,900

The belt speeds for *portable* engines of 10 hp. and larger shall be 2600 ft. per min., tractor belt-speed standard.
The variation in belt speeds shall not exceed 5 per cent above or below those specified.

EVOLUTION

AN engineering designer above all people should proceed along the path of progress by short and well comprehended steps. There should be no leaps in the dark. A slight change of detail in a mechanism frequently results in a performance or symptom that was not anticipated. Such a change may bring a result out of all proportion to the amount of the alteration made. Obviously, therefore, if a number of new, though comparatively small, changes are carried out simultaneously, the diagnosing or rectifying of more than one defect or trouble at a time may well prove to be a very complex and costly process. One experiment at a time should be an invariable rule.

A further point in connection with design is the apparent distaste of the purchasing public for goods that they may consider too novel. Objections on this point frequently hold good even in the case of articles that have been proved to be of greater efficiency and even of less cost than those produced to more conventional designs. To some extent this viewpoint is justified. For example, practically every adult residing in a civilized country comprehends, at least in some measure, the main features of the modern motor-car. As untrained minds often find considerable difficulty in grasping the technicalities of new mechanisms, motor-car designers are wise in adhering to what are considered orthodox general arrangements.

The all-important matter of cost also enters largely into any question as to the advisability of producing entirely new designs. Apart from the very considerable sums that must be expended on special tools, jigs, gages, etc., it is necessary to bear in mind that it requires some time for machine operators, fitters and assemblers to become thoroughly accustomed to new work. The more specialized the class of labor employed, the more serious does this consideration become. In other phases of works administration, drastic changes are likely to bring disastrous results. Many such instances come to mind. Systems require very careful handling both when they are being installed and when changed. Their apparent complexity when viewed for the first time as a whole is due, as a rule, to their gradual growth, and organizers, designers and others should take a lesson from nature and recollect that "Rome was not built in a day."—*Engineering Production* (London).

Steel[1]

By Dr. John A. Mathews[2]

BY many, the capacity for hardening in water has been considered as the distinguishing characteristic of steel. By others, it is considered that the preparation of this form of iron by a melting process is essential to distinguish steel from the other forms of iron, the result of melting the raw materials being largely to free them from the slag and the inclusions that are characteristic of wrought iron. The third quality generally considered as necessary is that of malleability. This distinguishes steel from cast iron. It is my opinion that the two really essential characteristics are manufacture by melting and the quality of malleability. It seems to me that the property of hardening should not be considered an essential of the definition. There was a discussion a few years ago as to whether the name *ingot iron* was the proper one to describe a well-known American product. This should be called *ingot steel.* It is extremely low in carbon and will not harden in the ordinary sense of the word by quenching in water. Nevertheless it is manufactured by melting in the open-hearth furnace and is malleable. It is free from slag and inclusions, and therefore should not be called iron, thereby likening it to wrought iron that has not been produced by a melting process, is not free from slag and inclusions, but is, of course, malleable. Hardening is a question of degree and the degree of hardening increases directly with the carbon-content. While a steel extremely low in carbon does not harden very materially as measured by the scleroscope and Brinell tests, such carbon as it possesses may be converted into the martensitic state by heating to a high temperature followed by a quick cooling. It may, therefore, be said to have been hardened, even though the physical hardness may not be materially increased, owing to the small amount of carbon. The martensitic form characterizes hardened steel, but the small amount of martensite is contaminated with so much free ferrite, which does not harden, that the final product will be physically soft.

In my opinion, steel as we now know it, the steel of commerce, made in Bessemer, open-hearth, crucible or electric furnaces, is that form of iron which has been produced by melting to yield a finished product that is malleable. The question of carbon-content and the incidental presence of other elements is not vital to the definition. When we wish to refer to steel of centuries prior to the invention of crucible cast-steel we may still use the term "steel" prefixed by "cemented," "blister," "shear" or "double shear." These forms of steel have continued at a diminishing rate of production down to the present time. Steel, as we know it today, began with the invention of cast steel made by a process of fusing, thereby eliminating slag and producing a practically homogeneous product in which the carbon and other elements were distributed uniformly throughout the product. The product was also malleable and therefore within the definition of steel based upon fusion and malleability. Steel prior to this time was produced without fusion, by the process of carbonizing wrought iron.

As to the use of the word *carbonize* and *carburize,* our metallurgists in general prefer the word *carburize* to indicate the process of adding carbon to low-carbon iron or steel products. I am inclined to use the word *carburize* in connection with the process of adding carbon to the molten products of open-hearth, electric or Bessemer furnaces. Carbon is added to molten steel in the form of anthracite coal, charcoal, ferromanganese and similar substances. Sometimes the process is carried out in the furnaces and sometimes in the ladles. The process of adding carbon to solid steel, as in the case-hardening operations, I am disposed to call *carbonizing.* Therefore, the old process of making a cemented steel would be considered a carbonizing process, the bars of wrought iron being packed in charcoal and subjected to heat for a period of 7 to 12 days in furnaces looking more or less like pottery kilns. The same word would apply to the modern practice of case-hardening small finished parts, such as gears.

It has been recognized for nearly 150 years that carbon is the element that confers on iron its wide variety of properties. When, in definitions of steel, carbon is included as an essential, it is generally stated that the carbon-content may vary from 0.10 to 2.00 or 2.25 per cent. The ordinary steel of commerce is well within these ranges. The true upper limit, however, is the limit of forgeability. Plain carbon-steels containing as high as 2.50 per cent of carbon can be forged with difficulty. The principal difficulty in forging the extremely high-carbon steels arises from the tendency of the excess cementite to break down into ferrite plus free graphitic-carbon. Certain elements tend to keep the carbon in combination and certain other elements tend to precipitate the free carbon in high-carbon steels. Manganese and chromium are the principal elements that tend to keep it in combination, while silicon and nickel tend to precipitate free carbon. In the carbonizing of steel the same elements act the same way; high chromium and manganese seem to facilitate the absorption of carbon, while silicon and nickel tend to retard its absorption.

In addition to the iron and carbon present in all commercial steels, there are four other elements ordinarily present whose effects must be considered. They are manganese, phosphorus, sulphur and silicon. These are often considered as impurities, since it is almost impossible to make steel free from them. The first two elements, however, especially manganese, must be considered essential and beneficial, while phosphorus and sulphur are nearly always undesirable. Copper and arsenic are usually present in minute quantities and, in the amounts ordinarily present, their effects are negligible. Aluminum is normally present not for the reason that it cannot be eliminated, but because it is added to the steel during casting and traces of it may be found in the finished product. Ordinary steel, then, by whatever process made, may contain carbon and manganese from 0.10 to 1.50 per cent; silicon from a trace to 0.25 per cent; phosphorus and sulphur from below 0.01 to 0.10 per cent; with copper, aluminum and arsenic in negligible quantities. Steel usually contains hydrogen, oxygen, nitrogen and cyanides in minute quantities that are not readily determined. Nevertheless, we must assume that each and all of these elements exert some influence in regard to the final quality of the steel. We have much to learn as to just how they act and as to what their influence is, particularly in regard to tool steel. It so often happens that two samples of steel, of practically identical analyses as far as the ordinary elements are determined, give such different service that we are forced to the conclusion that other factors than those that our present methods of investigation deal with control the ultimate quality. The mysterious something called quality is frequently called by the British *body.* Just what body is, I have never seen defined.

The term *alloy steel* has acquired a special significance, meaning any steel to which, in addition to carbon and iron and the impurities common to all steel, a metal or metalloid has been added to change or improve the natural properties. Chemically pure iron may be classed among the rare metals.

In general, it may be said that the influence of other elements upon an iron-carbon alloy is

(1) To change the temperature of the occurrence of the critical points

(*Concluded on p.* 609)

[1] From a paper presented before the New York Chapter of the American Society for Steel Treating.

[2] M.S.A.E. President of the Steel Co. of America, New York City.

Nebraska Tractor-Test Analysis

By Oscar W. Sjogren[1]

Chicago Tractor Meeting Paper *Illustrated with* Charts

A COMPILATION of all results of the tractor-testing work at the University of Nebraska is presented by the author, who specifies the equipment used and discusses the subjects of the proper rating of tractors, belt speeds, weight distribution, tractive efficiency, wheel slippage, piston displacement, fuel and water consumption in considerable detail supplemented by illustrations. The defects of tractors are divided into the three main groups of engine, accessory and chassis, and enumerated, comment being made thereon.

Three general recommendations for remedying these defects are stated and a statistical record of the results secured during the three seasons when the tests were conducted is included. That a better product is one of the direct results of the testing program is indicated by the statistics presented in Table 1.

THIS paper states the results of an extensive but by no means exhaustive study of the data secured in the tractor-testing work at the University of Nebraska. These data are so inclusive that even an extensive study of them cannot exhaust the possible different angles of attack. The data given are a compilation of all results. All comparisons made are based on actual performance records, and not on any personal preferences. The Nebraska tests are all carried out under as nearly similar conditions of operation as it is possible to secure, which fact makes an analysis of the results of more than ordinary value. The figures for the 1922 tests are not included in this study except where mentioned.

All belt tests were made on a Sprague electric dynamometer driven by belting the tractor to it with a belt of width and length as recommended for use with the tractor in ordinary operation. No allowance was made for belt loss, as it was contended that it is the power delivered to the driven machine that is to be considered in actual operation. The drawbar tests were run on a ½-mile track, which has been wrongly termed a cinder-track. It is true that cinders were used, but only to the extent of a thickness of about 2 in. mixed into the upper 8 in. of soil to improve drainage conditions.

Rating of Tractors

One of the outstanding discrepancies in the tractor field is the lack of standard methods of rating, in the belt and at the drawbar. For purposes of comparison, the table of rating shown in Fig. 1 was made up, in which the rated power is taken as 80 per cent of the maximum for both belt and drawbar. This shows that only 15 out of 76 tractors met this requirement on the belt, and 61 are rated above this. Seven of these were rated at a figure that they could not reach. On the drawbar, a much more liberal allowance is made as is indicated by the ratings in Fig. 2. Fifty-one tractors came up to or exceeded the 80-per cent rating, and 22 failed to reach it. Of these, two were rated at more than they could actually develop.

As measured by this standard, the ratings of a large

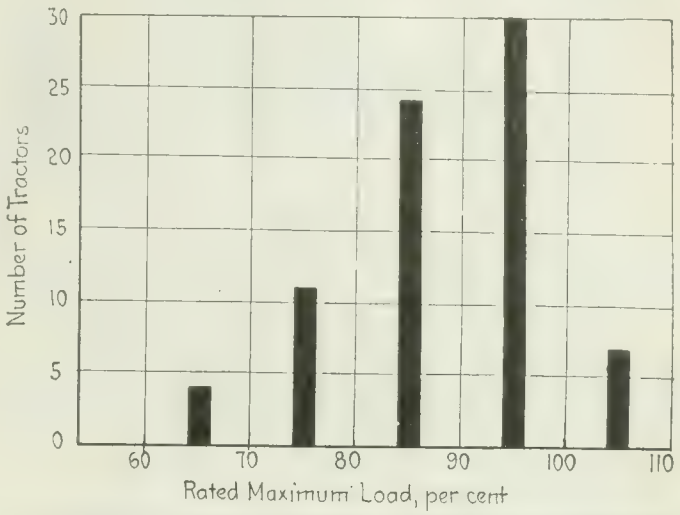


Fig. 1 Classification of Tractors According to the Relation between the Rated and the Maximum Belt Horsepower

percentage of the tractors are made on too narrow margins; very little if any allowance is made for individual differences in machines, or for possible power reductions as the tractor becomes worn. In several cases, tractors of different makes using the same kind and size of engine have been given ratings of wide variation. Three cases are cited, as follows:

(1) Four tractors of different make using the same engine are rated from 30 hp. at 900 r.p.m. to 35 hp. at 850 r.p.m., an increase of 16 per cent in rating with a 5½ per cent drop in speed

(2) Two tractors of different make using the same engine are rated at 20 and 25 hp., respectively, at the same number of revolutions per minute, a difference of 25 per cent

(3) Three tractors of different make using the same engine are rated at 12 hp. at 1000 r.p.m.; 10 hp. at 1000 r.p.m.; and 10 hp. at 1200 r.p.m.

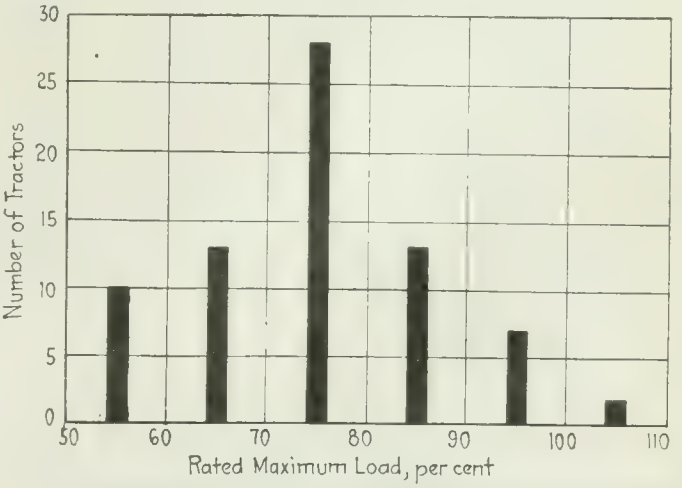


Fig. 2—Classification of the Tractors on the Drawbar Horsepower Basis

[1] M.S.A.E.—Professor of agricultural engineering, college of agriculture, University of Nebraska, Lincoln, Neb.

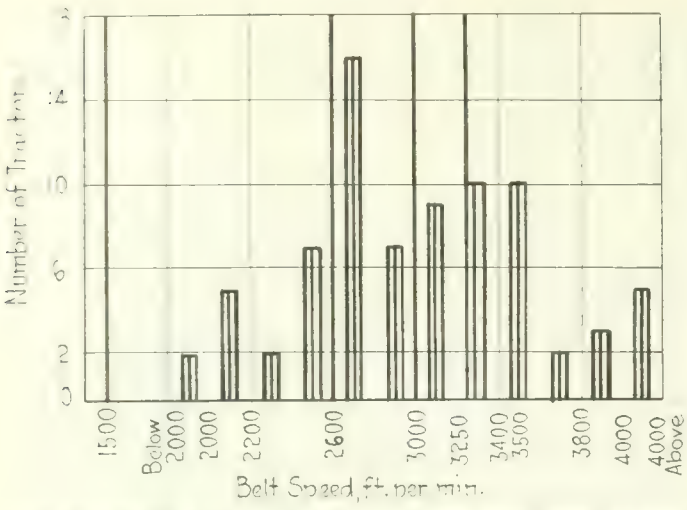


FIG. 3—DIAGRAM SHOWING HOW CLOSELY THE BELT SPEEDS OF THE TRACTORS TESTED CONFORM TO THE STANDARD RATES OF 1500, 2600, [illegible] R.P.M.

These cases are sufficient to indicate a condition the existence for which there is no legitimate reason. A standard method of rating, conscientiously observed, would give a direct comparison of tractors from the

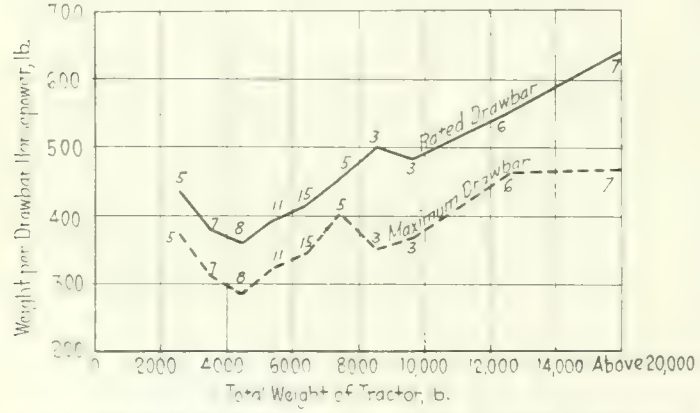


FIG. 4—RELATION BETWEEN THE WEIGHT PER DRAWBAR HORSEPOWER AND THE TOTAL WEIGHT OF THE WHEELED TYPE TRACTORS

power standpoint. This would tend to give prospective users greater confidence in the tractor industry, if they can be made to see and realize that all tractors similarly rated can be compared from the basis of power output.

BELT SPEEDS

Efforts have been made during late years to secure greater uniformity in the surface speed of tractor belt-

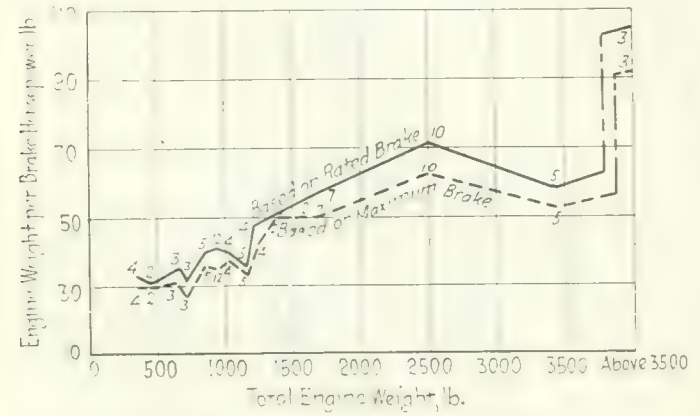


FIG. 5—RELATION BETWEEN THE ENGINE WEIGHT PER DRAWBAR HORSEPOWER AND THE TOTAL ENGINE WEIGHT

pulleys. Belt speeds of 1500, 2600, 3000, 3250 and 3500 ft. per min. have been designed as standard. Fig. 3 indicates how nearly present belt speeds conform to these standards. The heavy single lines indicate the figures adopted as standard. Here it seems is a place for great improvement. Why have so many different belt speeds? It evidently adds confusion. Possibly, wide limits are desirable when a standard is first proposed, but is it not time now to choose one or two definite belt speeds and to equip all machines with pulleys

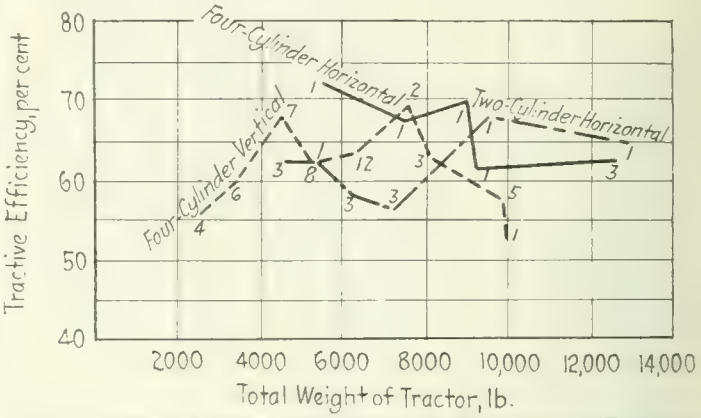


FIG. 7—CHART SHOWING THE RELATION BETWEEN THE TRACTIVE EFFICIENCY OF DIFFERENT TYPES OF ENGINE BASED ON THE MAXIMUM HORSEPOWER AND THE TOTAL WEIGHT OF THE TRACTOR

that will give these speeds at the rated number of revolutions per minute?

WEIGHT DISTRIBUTION

Upon first thought, one might easily assume that the very light tractors have less weight per drawbar horsepower than the heavier ones. However, the figures show clearly that this is not true. As given in Fig. 4, they indicate that the tractors having a total weight of about 4500 lb. have less weight per drawbar horsepower than either the lighter or the heavier ones. This relation

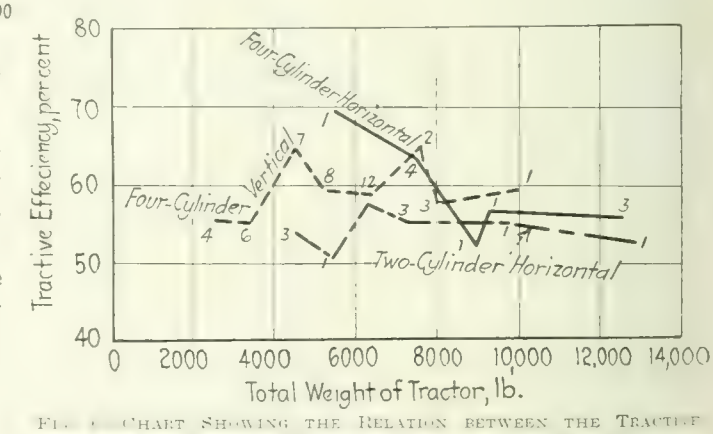


FIG. 6—CHART SHOWING THE RELATION BETWEEN THE TRACTIVE EFFICIENCY OF DIFFERENT TYPES OF ENGINE AND THE TOTAL WEIGHT BASED ON THE RATED HORSEPOWER

should be borne in mind later when making other comparisons. As is evident in Fig. 5, the general trend of the relation of total engine-weight and engine weight per brake horsepower indicates that the weight per horsepower increases as the total engine-weight increases. The three tractors represented in the lowest figure have a total average tractor-weight of 4060 lb.

TRACTIVE EFFICIENCY

The term tractive efficiency is applied to the ratio, or the percentage, of the brake horsepower delivered to

the drawbar; it is E = (Drawbar Horsepower/Brake Horsepower) x 100. Fig. 6 indicates the relation existing between total tractor-weight and tractive efficiency for the different types of engine. Here the 4500-lb. tractor is again to the front as it is in weight distribution, in that it has the highest efficiency in its class, except in the case of the tractor with a four-cylinder vertical engine. The other high point in this curve for a 7500-lb. tractor is obtained from the records of

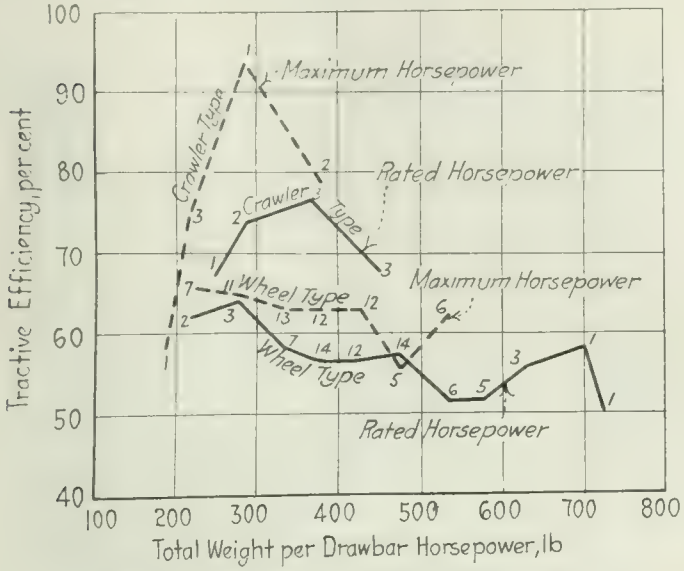


Fig. 8—Relation between the Tractive Efficiency and the Weight per Drawbar Horsepower for Different Types of Tractor

only two machines; it cannot be considered as conclusive as the point for the 4500-lb. weight, which is obtained from the records of seven machines. The points on the curve for the four-cylinder horizontal engine contain,

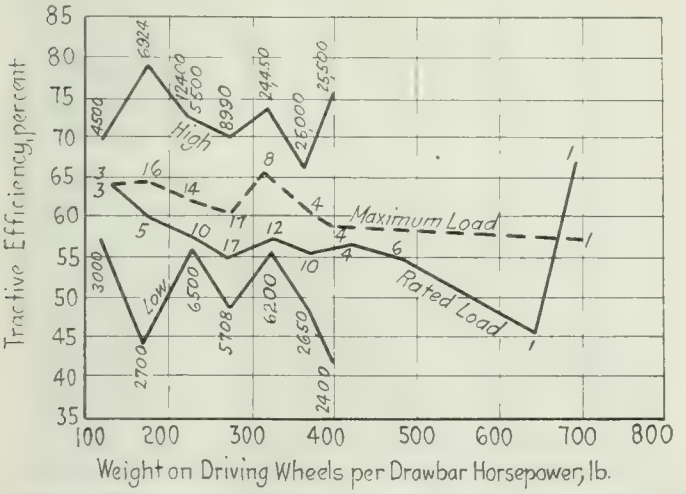


Fig. 9—Relation between the Tractive Efficiency and the Weight on the Driving Wheels per Drawbar Horsepower

with one exception, the records of only one machine. Likewise, the curve for two-cylinder horizontal engines cannot be considered as an average. However, the general trend is noted to be toward a reduction in the tractive efficiency with an increase in the total weight of tractor beyond the 4500-lb. weight. There seems to be also a tendency toward a decreased efficiency with tractors lighter than about 4000 lb. Fig. 7 indicates that the tractive efficiency based on the maximum tests runs in much the same general trend as on the rated tests.

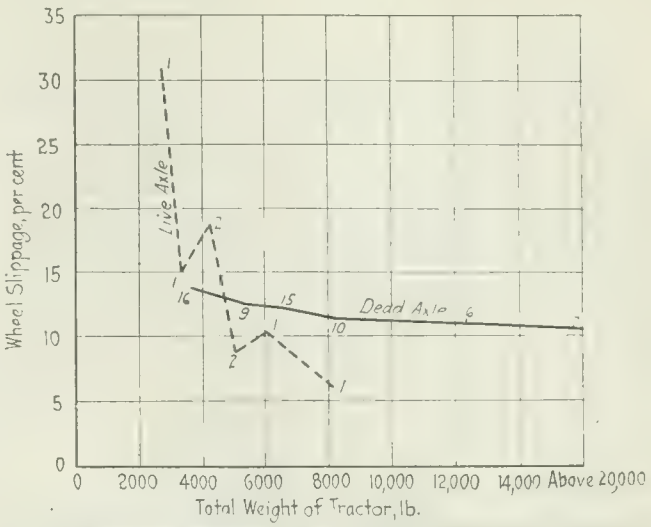


Fig. 10—Relation between the Tractive Efficiency Based on the Maximum Horsepower and the Total Weight of the Tractor According to the Type of Final Drive

With the wheel tractor, the efficiency tends to become lower as the total weight per drawbar horsepower increases, as shown in Fig. 8. The crawler type shows higher efficiency than the wheel type, but the number

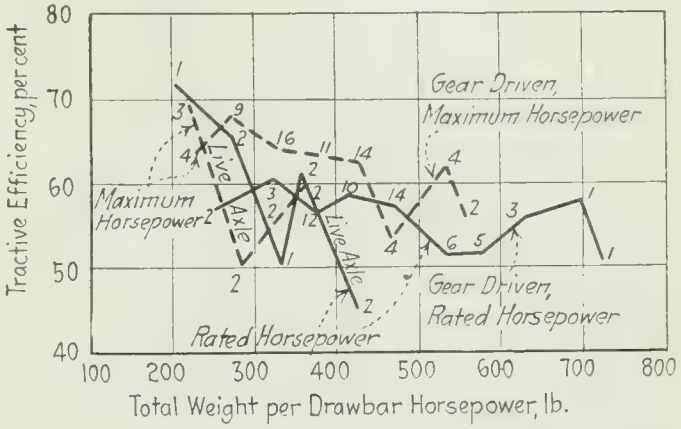


Fig. 11—Relation of the Tractive Efficiency and the Weight per Drawbar Horsepower for Different Types of Final Drive

of records available of this type makes it difficult to state correctly the general relation of the two factors considered. As indicated in Fig. 9, the general tendency is for the tractive efficiency to vary in an inverse ratio to the weight on the drivers per drawbar horse-

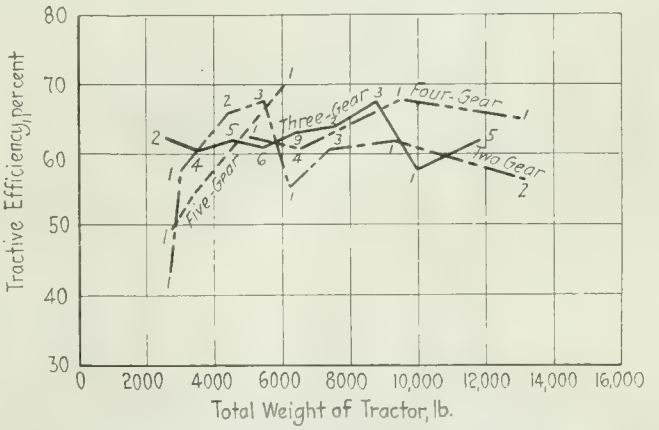


Fig. 12—Tractive Efficiency as Related to the Total Weight of the Tractor Classified According to the Number of Gear Reductions

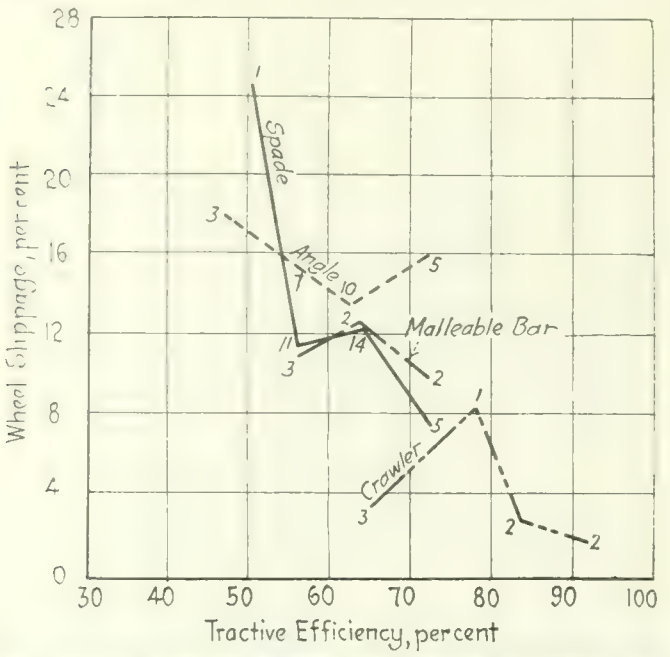


FIG. 13.—THE RELATION BETWEEN THE TRACTIVE EFFICIENCY AND THE MAXIMUM WHEEL SLIPPAGE WITH DIFFERENT TYPES OF LUG

power. The figures for the maximum load are the most significant, as they are based on the maximum tests and indicate more nearly the relation than does the rated curve. The highest and the lowest efficiencies in each weight class are indicated by the high and the low curves. The figures on these curves give the total weight of the tractor for each point. It is thus seen that the heavier tractors have the highest efficiency and the light tractors have the lowest. When considering the total weight of the tractor, however, this relation does not hold. In Fig. 10, the efficiency is seen to reach its apparent maximum for tractors weighing about 5000 lb., dropping slightly for the heavier machines.

A study of the relation of the tractive efficiency and the weight per drawbar horsepower, the results of which are shown in Fig. 11, indicates that the lightest-weight tractors are not so efficient as those of medium weight, except in the case of the live-axle-driven machines. The advantages of the live-axle-driven tractor are apparent only in the lightest weights. "Live axle" is the term used when the axle is keyed or fastened rigidly to the drive-wheels and is driven from a differential. The slight

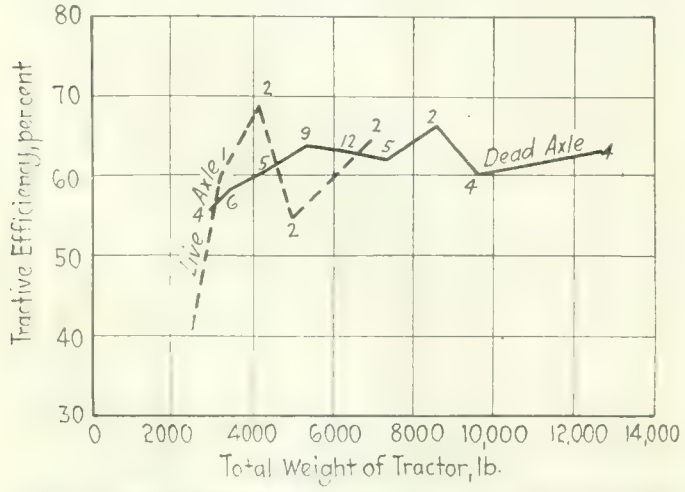


FIG. 14—WHEEL SLIPPAGE AS RELATED TO THE TOTAL WEIGHT OF THE TRACTOR CLASSIFIED ACCORDING TO THE TYPE OF FINAL DRIVE

advantage of the gear drive over the live-axle drive shown in these curves may be due to the greater number of machines in the gear-drive class on which data are available.

Some discussion has been heard in various tractor meetings about the probable effect of the number of gear reductions on the tractive efficiency. A study of the data reveals average conditions, as indicated in Fig. 12, that no one number of gear reductions has the advantage with respect to tractive efficiency.

WHEEL SLIPPAGE

One of the factors in tractor operation that seems to give considerable trouble is that of slippage of the drive-wheels. The power available at the drawbar is limited by one of two factors: (*a*) inability of the drive-wheels to maintain a grip on the ground firmly enough to pre-

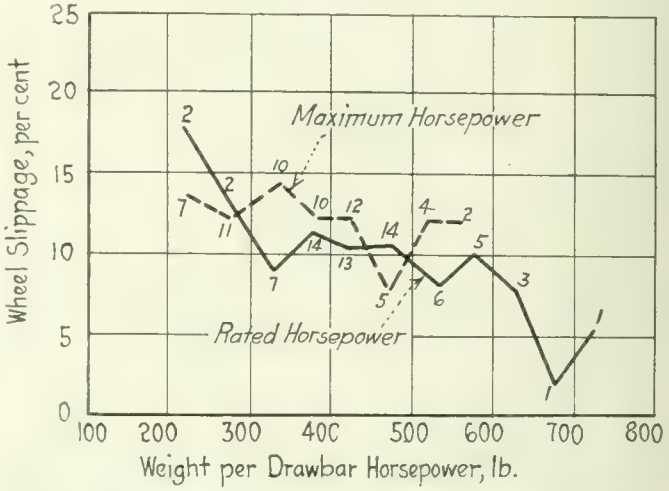


FIG. 15—IN GENERAL THE WHEEL SLIPPAGE TENDS TO DECREASE SLIGHTLY AS THE WEIGHT OF THE TRACTOR PER DRAWBAR HORSEPOWER INCREASES

vent slippage with heavy loads, or (*b*) insufficient engine power evidenced by stalling of the engine with heavy loads. Considerable effort and thought have been given by tractor designers in attempts to balance these two factors. All slippage data are taken as being at the point of a lug.

A consideration of the effect of different types of lug on wheel slippage for various values of tractive efficiency is shown in Fig. 13. The lug equipment showing the best results in these tests will not necessarily show the best results under conditions differing from those existing on the testing track where these results were obtained. The tendency of the angle lug was to pulverize the surface of the track, after traveling over it several times, to such an extent that a good grip could not be secured. This condition would not arise where the tractor breaks a new path continuously as in farm work. The spade lugs gave the best results on the track, due largely to the fact that they would penetrate the ground to a sufficient depth to give a good grip and therefore would not cut or pulverize the surface. The malleable-bar lugs were used on the largest tractors which, in themselves, were heavy enough to cause the wheels to grip the ground. It is doubtful if this type of lug would give any better results on the light tractor than did the angle lugs. The crawler-type tractors show a very low percentage of slippage, as would be expected.

Fig. 14 shows that as the total tractor-weight increases the percentage of slip of the drive-wheels de-

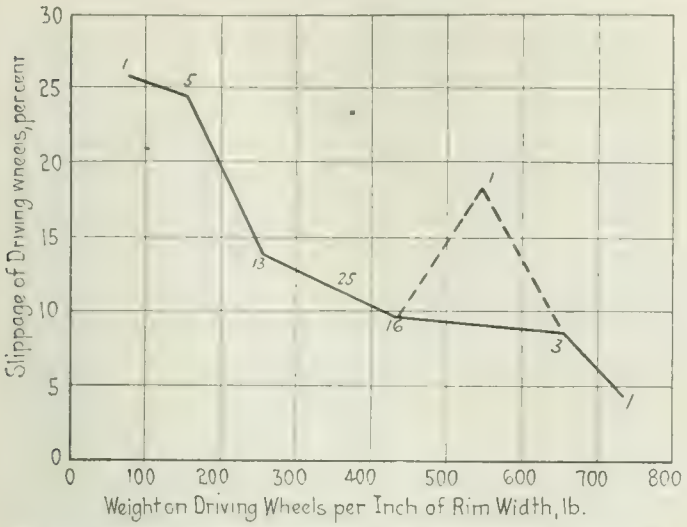


FIG. 16—DRIVING WHEEL SLIPPAGE AS RELATED TO THE WEIGHT PER INCH OF WIDTH OF THE DRIVING-WHEEL RIMS

creases slightly. The better showing made by the dead-axle type probably is due to two conditions: the larger number of machines of this type from which data could be obtained, and the fact that the heavier machines which, because of their weight, tend to have a lower percentage of wheel slippage, were also of this type. Fig. 15 indicates in a general way the tendency of wheel slippage to decrease slightly as the tractor weight per drawbar horsepower increases. This tendency to de-

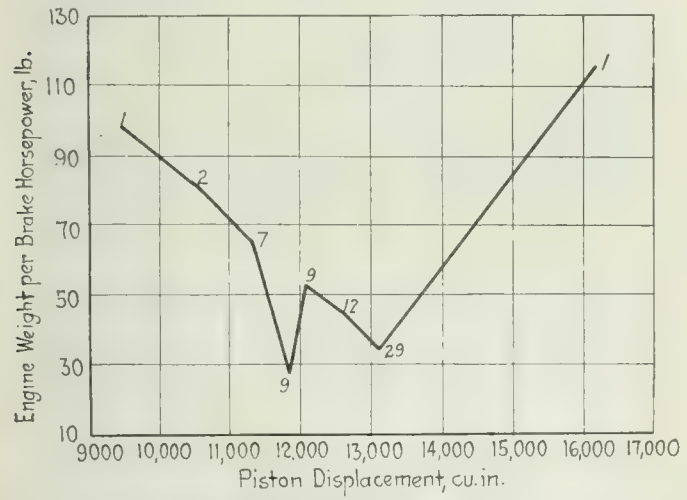


FIG. 17—RELATION BETWEEN PISTON DISPLACEMENT AND THE ENGINE WEIGHT PER MAXIMUM DRAWBAR HORSEPOWER

crease is more marked in Fig. 15 than in Fig. 14. Very many factors enter into the problem of wheel slippage, and many studies have been made of various combinations of the data, bringing into consideration the diameter of the drive-wheels, the speed of travel, the drawbar pull and the horsepower. No general tendency of the effect of these factors could be noted. Fig. 16 indicates the factor that gave the most consistent results. If all operating and soil conditions could be kept constant, no doubt some rules or some formula would be discovered that would aid materially in the design of tractors to overcome the tendency of the drive-wheels to slip under a heavy load.

Wide differences of opinion exist among tractor men as to the advantages and disadvantages of rating tractors on a piston-displacement basis. The discussion by those favoring this method of rating seems to center about the figure of 13,000 cu. in. per min. per hp. The data show a great variation in this factor among the tractors tested. Fig. 17 indicates that the large majority of tractors have a piston displacement ranging from a little above 11,000 cu. in. to slightly more than 13,000 cu. in. per min. per hp.

How the piston displacement varies with the type of engine and the engine speed is shown in Fig. 18. The evidence here is to the effect that the designers of the four-cylinder vertical engines have come closer to a standard design of performance of engine than have the designers of horizontal engines. Upon a closer ex-

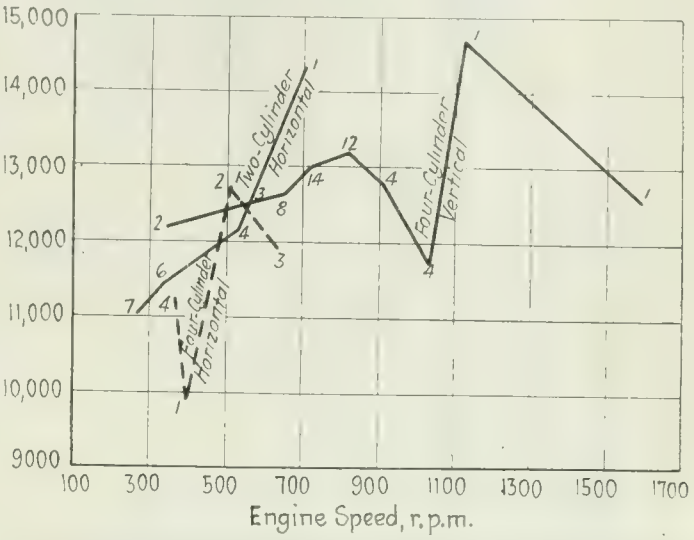


FIG. 18—PISTON DISPLACEMENT OF DIFFERENT TYPES OF ENGINE AS RELATED TO THE ENGINE SPEED

amination of the original data, however, it is found that the highest as well as the lowest figures for piston displacement are found in this class, the former being 16,740 cu. in. and the latter 9150 cu. in. The favorable showing in Fig. 18 is therefore due to the greater number of machines in this group, rather than to any uniformity of design or performance.

In the matter of the relation of the piston displacement to the diameter of cylinders and the engine speed, the indications are that the large-diameter cylinders run at lower speeds but do not necessarily have a lower piston-displacement than those of small diameter. The medium-diameter cylinders, those of from 5 to 6 in., seem to run the lowest as a group in piston displacement and at speeds from 600 to 800 r.p.m. The lowest piston-displacement mentioned above was made with a piston diameter of 4 1/8 in. at 1200 r.p.m.

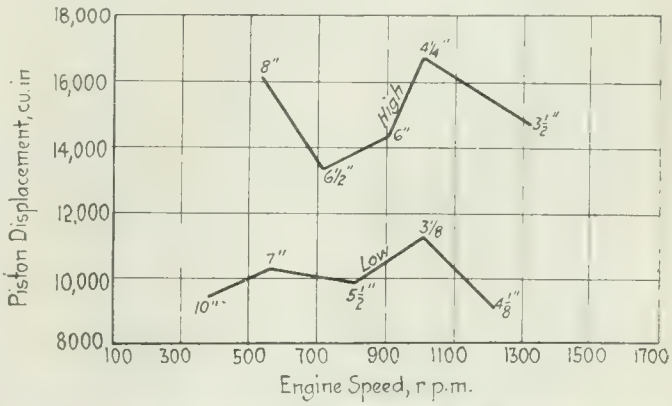


FIG. 19—RELATION BETWEEN PISTON DISPLACEMENT AND ENGINE SPEED FOR TRACTORS HAVING CYLINDERS OF DIFFERENT BORES

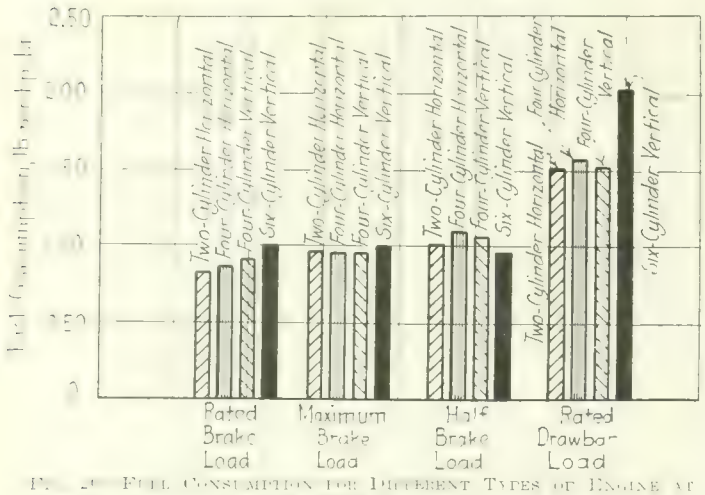


FIG. 20—FUEL CONSUMPTION FOR DIFFERENT TYPES OF ENGINE AT VARIOUS LOADS

The high and the low limits between which piston displacement varies are given in Fig. 19. They show a great variation in this factor and constitute evidence that engine design is not nearly standardized as yet.

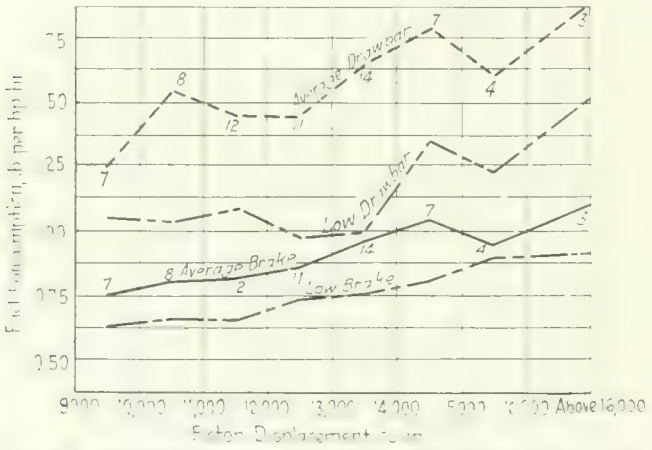


FIG. 21—RELATION BETWEEN THE FUEL CONSUMPTION AND THE PISTON DISPLACEMENT ON VARIOUS LOAD BASES

The curves indicate that the optimum speeds, as based on piston displacement, lie between 600 and 1000 r.p.m.

FUEL AND WATER CONSUMPTION

Lowering of the fuel consumption per horsepower-hour is one of the main aims of many tractor builders. That there is a great variation in the amount of fuel used per horsepower-hour is indicated by the test records. The original data disclose that the lowest fuel-consumption was 0.63 lb. per hp-hr., on the rated brake-load and 0.67 lb. on the maximum brake-load, the same tractor making both records. On the rated drawbar-test, this same tractor used 1.04 lb. per drawbar hp-hr. On this test it was equaled by one and excelled by two other tractors. The two low machines used 0.98 and 0.99 lb. per drawbar hp-hr., respectively. The highest fuel-consumption on the rated brake-test was 1.40 lb. per b. hp-hr. and, on the drawbar, the highest consumption was 2.76 lb. per drawbar hp-hr. It is thus seen that there is a great variation in the amount of fuel required per horsepower-hour for the various tractors, a variation of 138 per cent from lowest to highest on the belt test, and 181 per cent from lowest to highest on the drawbar.

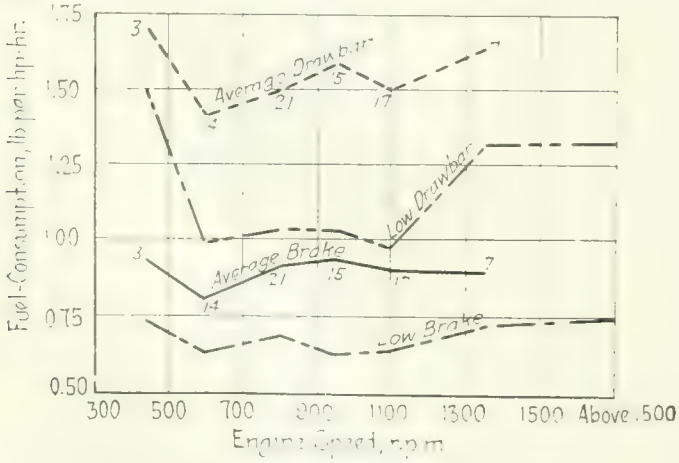


FIG. 22—FUEL CONSUMPTION AS RELATED TO THE ENGINE SPEED BASED ON THE RATED LOADS

Fig. 20 shows the fuel consumption for different types of engine on the various loads, and that no particular type of engine has the advantage throughout all the tests. All are fairly close together on the maximum belt-test, which is the most significant test so far as figures relating to performance are concerned. As would be expected, the fuel consumption tends to increase with an increase in the piston displacement. In Fig. 21, we have an average fuel-consumption for each group of tractors based on the piston displacement. Inasmuch as the tendency is to decrease the fuel consumption, only the average and the low curves are given.

The data showing the relation of the fuel consumption to the engine speed give peculiar results as shown in Fig. 22. Here it is seen that the lowest records are obtained at speeds between 600 and 1100 r.p.m. The data reveal that the lowest fuel-consumption is secured with engines having a diameter of cylinder of between 5 and 6 in.

Referring to Fig. 23, the relation of the tractor weight to the fuel consumption is somewhat surprising, especially in the horizontal-cylinder engine, in that it tends downward as the weight increases. This holds true until an approximate weight of 7000 lb. is reached, after which the curve assumes an upward tendency. In the case of vertical-cylinder engines, there is a slight upward tendency in the curve until the above weight is reached and then the curve drops very markedly. However, the number of tractors used beyond that point is small as compared to those used at the other weights, which fact may materially influence the results.

Fig. 24 indicates that the I-type engine will give better fuel-economy than the L-head engine on all operating loads. This same advantage is noted in Fig. 25, where only four-cylinder vertical engines are considered. Some interesting comparisons of the fuel consumption at various loads are given in Fig. 26. The rated brake-load gives a better economy than either the maximum or half loads. The relation is also brought out that the fuel requirement on drawbar work is almost double that required on belt work per horsepower-hour.

The water consumption per hour for the different tractors showed a wide variation, running from no water used during the 2-hr. rated-horsepower test with the air temperature at 84 deg. fahr. to 40 gal. for the same test with the air temperature at 88.5 deg. fahr. On the drawbar test, the amount of water required varied from no water used with air temperature at 87 deg. fahr. to 17.8 gal. per hr. at the same air-temperature. This wide difference in the amount of water used indicates that in some cases the cooling system has not been given the attention that it really deserves.

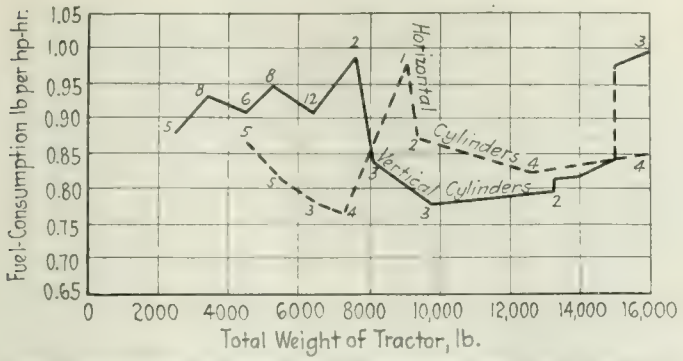


FIG. 23—RELATION OF THE TOTAL WEIGHT TO THE FUEL CONSUMPTION FOR DIFFERENT TYPES OF TRACTOR ENGINE

DEFECTS OF TRACTORS

This discussion of the defects that have shown-up in our tests is intended to be critical only in a constructive sense; the defects are mentioned in the hope that a closer study of the requirements will be made and more

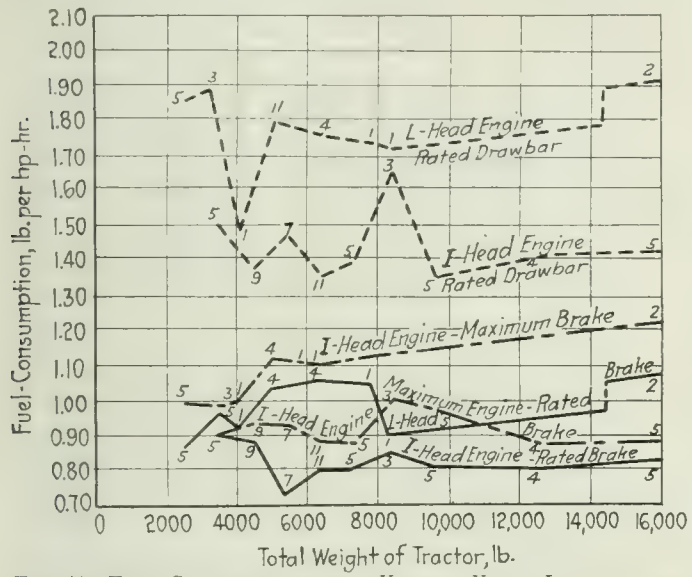


FIG. 24—FUEL CONSUMPTION WITH VARIOUS VALVE LOCATIONS AS RELATED TO THE TOTAL WEIGHT OF THE TRACTORS

rigid inspection required of all parts that go to make up the tractor, so that the final result will be a more highly improved product.

The minimum time on test for any tractor was 30 hr. of operation; and the maximum, 78 hr. All the defects mentioned have shown-up within these time limits and indicate that the tractor user must be not only an operator but a mechanic from the very first. The defects have been divided into three main groups, those dealing with the engine, the accessories and the chassis; the figures refer to the number of tractors in each case.

ENGINES

In regard to the engine and in addition to several minor defects, we note from our records the following main items:

Defective Cylinder-Blocks Replaced	3
Cylinder-Heads Replaced	1
Gaskets Burned-Out	3
Cylinders Scored	2
The main defects of the valves were as follows:	
Valves Replaced	2
Stems Ground	2
Valves Ground	4
Springs Broken	1
Push-Rods Adjusted	13

Some of the push-rods had to be adjusted several times. The necessity of adjusting push-rods should not of course be classed as a defect in the regular sense, as such adjustment is an ordinary proceeding; but the number of cases of this during the time of the testing is striking. In many of these cases the power output was increased materially. Frequently the indications were that the valves had not been fitted properly at the factory. Timing of the valves was changed in two cases.

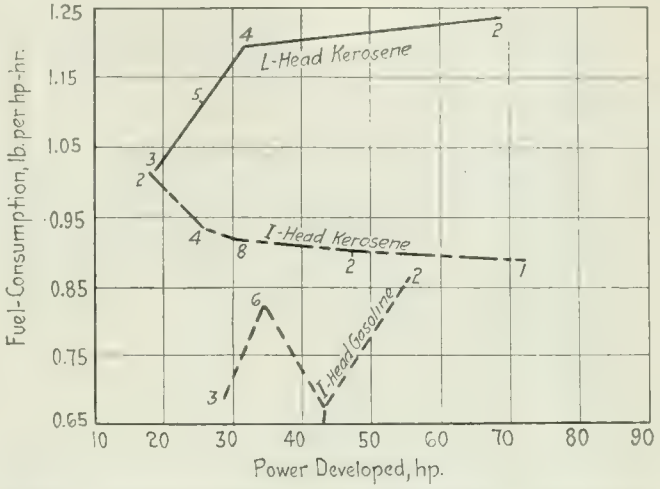


FIG. 25—RELATION BETWEEN THE FUEL CONSUMPTION AND THE MAXIMUM HORSEPOWER OF THE TRACTORS CLASSIFIED ON THE BASIS OF VALVE LOCATION AND KIND OF FUEL

Belt pulleys of the attachment type gave the most trouble, probably due to the short shaft and the fact that only one bearing was used. Lack of proper clearance between the pulley and the drive-wheel was encountered. This is especially undesirable when the tractor is used on wet ground; the soil fills-in on the drive-wheel to such a thickness that it rubs on the belt pulley and stalls the engine. The cranking of the engine while in the belt can readily be facilitated in some cases.

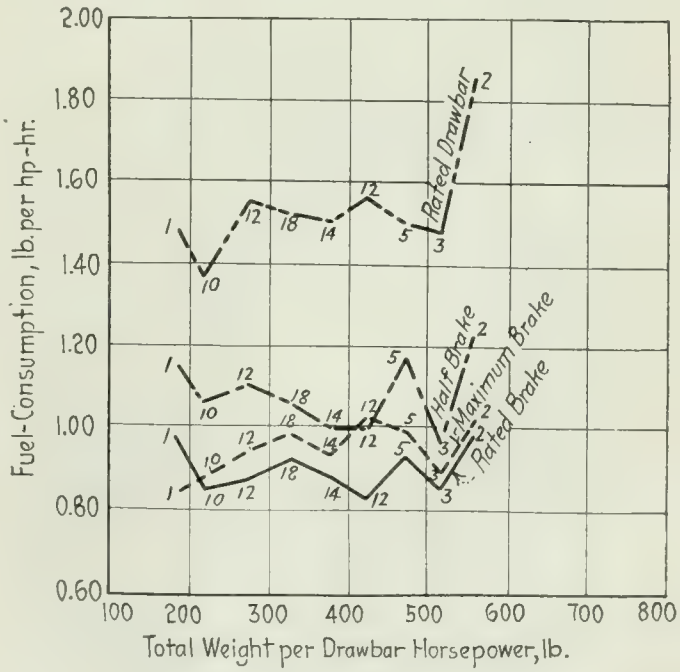


FIG. 26—THE FUEL CONSUMPTION AT DIFFERENT LOADS AS RELATED TO THE WEIGHT PER MAXIMUM DRAWBAR HORSEPOWER

CHANGES MADE IN ENGINES SUBMITTED FOR TEST

Crankshaft	
Bearings Refitted	1
Bearings Tightened	1
Connecting-Rods	
Bearings Adjusted	2
Bearings Burned-Out	1
New Grease-Cups	2
New Grease-Cup Caps	2
Pistons	Sets
Rings Butted	3
New Sets of Pistons	3
Pistons Turned-Down	2
Refitting Rings	1
Oiling System	
Pumps Repaired	2
Pressure Gage Not Indicating	1
Enlarged Suction-Pipe	1
Broken Pipes	3
Crankcase Floats Indicating Wrong Level	1
Belt Pulley	
Clutch Removed	1
Drive-Chain and Sprocket Broken	1
Whole Assembly Replaced	1
Replaced Lagging	1
Broken Pulley	1

Accessories

Cooling Systems—Most of the difficulty with cooling systems seemed to be in the matter of fans and fan drives. In 21 cases the fan-belt was the chief offender, requiring frequent tightening, replacing or relacing. In two cases the fans were replaced with larger ones. The same thing was true in the case of the radiators. Other difficulties related to the fan bearings, the pump packing, the water lines, and the valves. In some cases the cylinder-heads became very hot, even though the cooling water did not exceed a temperature of 200 deg. fahr. This may have indicated restricted circulation or that the water space was too small in the cylinder-head.

Clutch—Adjustment of clutches was necessary in 20 cases. Other difficulties were: clutch stuck, broken shoe, broken link, completely wrecked, collar bolts broken, throwout-arm loose and pin lost.

Fuel System—In seven cases, the carbureter was replaced with one of a different size or make and in several other instances changes in the carbureter that were made improved the operation of the engine materially. Altogether, 50 changes on fuel systems are recorded; several of these may have been on the same machine. Some of the changes and jobs aside from those already mentioned were: installation of bypasses and shrouds that permitted the regulation of the proportions of hot or cold air, thus regulating the temperature of the fuel mixture; nozzle size increased; air valve; the adding of a fine adjustment to the water-feed; leaks, and breaks in the fuel lines.

Air-Cleaners—In some cases the power output of the engine was increased materially by disconnecting the air-cleaner, indicating, in most of these instances, that the cleaner was too small. Another important factor brought out in the matter of the air-cleaners using water was the desirability of having them designed so that water can be added while the engine is under load. This is especially important when working in the belt.

Governors—The purpose of a governor on an engine is to prevent any appreciable variation in the engine speed. In many cases the governor is a governor in name only. That a governor can be built which really governs is shown by the many cases where close regulation is secured under a great variety of conditions. To be effective, a governor should not only control the speed of the engine throughout a load range from no load to full load, but should also allow the engine to develop its full power at rated speed when necessary. The most frequent difficulty encountered with governors, aside from ineffectiveness, was in the matter of springs; these were replaced in five cases. Other difficulties were wrong assembly and the replacement of parts.

Ignition—The most frequent difficulty encountered with ignition systems was in the matter of timing. This was changed in nine instances; magnetos were replaced in two instances. Other difficulties were: spark-coils replaced, the replacement of the breaker-points, the adjustment of breaker-points, loose couplings and impulse starters.

Chassis

Difficulties with the chassis were relatively few, and can be classed as (*a*) lack of proper lubrication; (*b*) poor steering-gears; and (*c*) weak construction evidenced by broken bolts, twisted frames and broken gears.

The weight distribution or method of attaching the load is sometimes such as to take nearly all of the weight off the front wheels, making guiding very difficult; or, on the other hand, so much weight is thrown on the front end as to make the steering apparatus very difficult to work, unduly tiring the operator.

Of the large number of tractors submitted for test, two entire tractors were replaced, one because of a defective engine and one because of a twisted frame.

More attention should be given, in the design and construction of tractors, to the comfort of the operator. This refers especially to seat design and arrangement. The operator should be able to sit so that he has a good view of the field ahead of him. The seat should be in such a position that the operator will not be directly in the path of the hot air from the fan blast nor be required to sit close to exhaust pipes or other highly heated material. The machine should be designed so that it is readily accessible in all parts for inspection, adjustment and repair.

If I were asked to make recommendations as to how these defects can largely be remedied, I would consider the following in the order of their importance:

(1) More rigid tryouts in the field under various conditions, by men other than the designer, before the tractor is finally approved for production
(2) A choice of accessories based on a thorough study of them as related to the particular machine in question
(3) More rigid inspections of parts, as well as of the finished machine

When I asked our engineer what he considered a great fault of the tractors he said: "They make a good tractor and then spoil it by using unsuitable accessories."

Results of the Tests

The following is a brief statistical record of the results secured during the three seasons the tests mentioned have been conducted:

Requests for Tests	141
Appeared for Test	89
Made Test without Changes in Tractor	51
Made Test with Changes in Tractor	35
Withdrew from Test	3
Changes Made	
Did Not Make Original Rating	12
Changed the Number of Revolutions per Minute	6
Changed Equipment	17

(*Concluded on p.* 609)

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

TIRES—OLD AND NEW

WHEN a new development changes some basic condition on which an industry or a product has been developed, the new possibilities in the way of further development made possible by the new conditions are often very slowly realized. When a given process has been carried on in a fixed way for a long time it is not easy to remember all the reasons why the process is as it is and how new conditions can permit of improvements or what changes they demand.

One of the most rigidly fixed conditions that have determined the progress of design in passenger vehicles is the standard pneumatic tire. Without the Otto-cycle engine and the pneumatic tire or their equivalent, as yet undiscovered, the automotive industry in its present form would not exist. The only other single element that remotely approaches either in importance is the electric starting-system. While tires have developed in reliability and general performance perhaps as much as have engines in the past 20 years, there has been no marked change in the action of the tire as a mechanical cushion for the vehicle. If a set of the tires and wheels of 20 years ago could be placed on almost any car of present-day design the average person probably would not notice the differences in the mechanical behavior of the vehicle.

Whatever are the reasons why tires have been made for 20 years with about the same tire diameter for a given load, about the same wheel-base diameter, about the same inflation-pressure and even roughly the same flexibility of the carcass, the fact that this has been the custom necessarily has been one of great importance in determining the design of many elements in chassis and body assemblies. In fact, hardly any important part of the vehicle has been unaffected by the mechanical conditions imposed by the degree of vibration that the tires permit to reach the other parts of the vehicle.

The prospect that the industry may introduce, or be introduced to, a type of tire differing radically in most of its mechanical characteristics from the present type opens a very interesting field of speculation as to what may be expected in the future. Some of the features of design that are most directly dependent on tire characteristics can be predicted, however, without much speculation. The possibility or probability that the general adoption of some form of tire giving a degree of cushioning that is distinctly more effective than that of the present type will make possible important modifications of design in the direction of lower cost and longer service, as well as greater comfort, invites a careful study of the different possibilities by automotive engineers. We shall attempt here merely to suggest a few of the more obvious features in which such a new type of tire may open up possibilities for advances in car design.

The outstanding feature of any prospective tire development is a reduction in the average and the maximum accelerations, not only vertical but perhaps also longitudinal and transverse, that can be imparted to the chassis by the reactions of the road. The reduction of impact should be more marked for the small irregularities of road surface than for the large ones, that is, for block pavements than for road "corrugations." This seems obvious without further comment. The following suggestions are based on a comparison between the standard and the prospective type of tire in this respect.

Axles and Wheels

Since the reduction of the ratio of the unsprung weight to the total weight has always been recognized as a desideratum, it is safe to assume that the weights and the sizes of front and rear axles have approached a minimum practicable limit for economic production. Even more than most parts of the vehicle, the axle sizes have been the result of practical experience rather than of theory and computation and this experience has been obtained with the standard types of pneumatic tire.

Since the more severe stresses to which an axle housing or a front axle is subjected arise from impacts or accelerations imparted to it through the tires, a reduction in the maximum stresses thus produced or in the number of times the stress exceeds the safe limit for repeated stress will necessitate less strength and less weight in the axles. We would predict, therefore, that for a given degree of reliability the axles for use with more flexible tires could be made lighter, but how much lighter probably only either experience or a systematic research on axle accelerations can determine. For this reason, and also because the transverse shocks are cushioned to a greater extent, the strength of the wheels can probably be reduced. But as the change in the tire size requires a different rim-size and perhaps involves a different tire-weight, one can hardly predict anything about wheel weights.

It is not clear just what factors have determined the present practice as regards wheel diameters, but probably body height, road clearance and other considerations have had as much to do with this as tire characteristics; hence it may be doubted whether modifications in the tires alone will cause any radical changes in wheel diameter.

Springs

Much has been written on the subject of springs, mainly from the point of view of cushioning the frame against the vertical displacements due to road irregularities. Not much attention seems to have been given to the question of cushioning the fore-and-aft or the transverse shocks, nor to the elimination of the minor vibrations that are due to resonance effects in the springs themselves. Effects of the latter sort are undoubtedly of much more importance as regards the comfort of the passengers and the vibration effects on the vehicle than has been generally recognized. They are perhaps responsible for most of the minor vibrations that are chargeable to the road, yet we know of nothing in print that deals directly with this subject.

Whatever is the nature of the spring reactions that are responsible for these effects, they are influenced mainly by the impacts of the wheels on the road as evidenced by the marked effect of tire inflation. It is to be supposed, therefore, that the reduction or the practical elimination of these secondary spring-actions would be the main result of the substitution of softer tires.

It is evident that there are two qualities of springs that might be subject to change to better adapt them to the new tires. These are the damping and the initial deflection. In fact, these are the only differences between them as regards their simple vertical reactions. Torsional rigidity, method of shackling and the like, of course affect the rolling and the

pitching periods and the horizontal rigidity of the suspension.

For practical reasons of clearance and capacity for variable load, the initial deflection is perhaps limited to about the present practice, except for some radical departure such as adjustable spring-tensions. However, the optimum amount of friction or damping effect of the springs or of shock absorbers that supplement this effect may be dependent on the tires. The use of tires that give to the axle upward accelerations on impact with the ground, which are comparable with the downward accelerations produced by the springs and not many times greater than the downward accelerations, may require an entirely different amount of damping of the spring action.

Frame Stiffness and Body Structure

The extent to which the dimensions of the frame members are fixed by the excess loads placed upon them by spring reactions is probably not well known. If these reactions are an important factor in fixing the stiffness of the frames, however, important changes in the frame dimensions and design might ultimately result from the adoption of the new style of tire.

The immense amount of effort that has been put into the design of bodies, particularly closed bodies, to keep them quiet and intact under the punishment of vibration, suggests that the body designers might find some of their worst troubles lessened or lost if the tires would take over a much larger share of the problem of cushioning road-shocks.

Weight in General

If it should come about that the unsprung weight can be reduced by virtue of a softer tire-action, and particularly if the stiffness of the frame and the body work can be reduced for the same reason, there appears to be a possibility of much reduced car-weights, together with greater comfort of the passengers. We are fully aware that the foregoing random discussion contains no definite facts whatever. Its object is not to present facts but to suggest that the progress of passenger-car development during the next few years, particularly if a new and softer style of tire is generally adopted, can perhaps be greatly hastened by a systematic investigation of the several features of design, some of which are suggested above, that may be radically influenced by changes in the mechanical behavior of the tire equipment.

SPREAD IN PRODUCERS' AND CONSUMERS' PRICES

THE public, in this country at least, has grown to expect such a variety of goods and services that more people are engaged in the secondary processes than are engaged in primary production. To be exact, of 41,614,248 people engaged in gainful occupations in this country, 29,570,867, or about 71 per cent, are engaged in manufacturing, transportation, distribution and allied activities. In view of these figures, why regard it as extraordinary that the primary producer gets less than one-half? The fact is that we are accustomed to a narrow meaning of the term "production." The act of transportation from one section of the country to another, or of delivering from the grocery store to the kitchen, is part of the process of producing the commodities *where* they are wanted, and every act of grading or preparing them for market is part of the process of producing them *as* they are wanted by consumers who are located at more or less distant points.

There is a common theory that a great number of superfluous people have interposed themselves between the producers and the consumers, but common observation should teach that the buyers are always studying how to get to the original sources and procure their supplies as cheaply as possible. The idea that goods may be handled over and over indefinitely, with each holder exacting a profit without rendering any service, is too simple to be believed by anybody who has had much business experience.

The Joint Congressional Commission of Agricultural Inquiry finds that the development of more expensive methods and service in distribution is in obedience to the wants of the public, and that it is useless to decry such methods if the public insists upon having them. The Commission suggests that one obvious point where a start can be made is the elimination of countless thousands of varieties, kinds, styles and sizes. The stocks of goods offered consumers have become multiplied beyond all reason, necessitating the carrying of much larger stocks than are necessary on the part of dealers, thus tying up much material and credit, all of which has ultimately to be borne by the consumer. Nevertheless, a dealer who has the variety makes an appeal that is persuasive with the average buyer.

The growth of cities is another factor in higher costs to their inhabitants. The congestion of traffic and the physical difficulties that attach to city delivery are increased as population grows.

The Commission attributes much of the spread to the poor market facilities for perishables that exist in many American cities. The report states that it is the belief of the Commission that the lack of properly established joint terminal markets is responsible for many of the extravagant costs in the distribution of agricultural products and that steps should be taken by municipalities, transportation companies and marketing agencies to create facilities for the efficient handling and the conservation of foodstuffs.—National City Bank.

AUTOMOTIVE VEHICLE INSURANCE

THERE are 20,000 motorbuses in operation; 600 cities have organized motorbus lines. There are 60,000 garages in the country; 55,000 repair-shops; 50,000 passenger-car and motor-truck dealers. Six billion people are carried annually by motor cars, and over 1,000,000,000 tons hauled annually by truck.

In rating cars from the insurance standpoint they are divided roughly into

(1) Private passenger
(2) Commercial
(3) Public, those used for transportation of passengers for a consideration
(4) Garages
(5) Automobile dealers
(6) Manufacturers

A private passenger-automobile is any gasoline or steam car of the private-passenger type used for pleasure or business purposes. A commercial automobile is any machine of the truck or delivery type. This includes a number of odd classes such as ambulances, fire-department automobiles, industrial trucks and tractors. Public automobiles include any machine used for carrying passengers for a consideration.

The average liability claim today costs about $300, exclusive of loading expenses. The average property-damage claim is about $35 or $40. The average collision loss is about $75. Large personal-injury verdicts are common and warrant selling limits on policies that are larger than $5,000 and $10,000.

Automobile risks having 10 or more machines under one ownership and operating management can have a special rate that is known as an experience rate made, provided the owner has been insured for 2 or more years and provided a premium has been received on at least 10 machines for 21 consecutive months.—O. M. Doyle, Standard Accident Insurance Co.

The General-Purpose Farm Tractor

By C. M. Eason[1]

Chicago Tractor Meeting Paper *Illustrated with* Photographs and Drawings

THE author divides the history of the application of mechanical power to farm work into three periods, reviews each one and comments upon the various phases of progressive development that influence the type of tractor most desirable for satisfying present needs. The requirements of farm work are outlined, and the different types of tractor built and being constructed to meet these demands are reviewed, discussion of large versus small tractors, type of drive, power needed, control, methods of operation and the factors constituting general-purpose service being included.

So far as adopting the tractor for farm usage is concerned, the author believes that the present limitation of such utilization lies with the tractor industry and with tractor engineers, rather than with the farmer.

THE history of the application of mechanical power to farm work can be divided into three major periods. The first, from about 1880 to 1910, covers the practical use of the steam engine for the operation of both grain separators and heavy plowing. The second period, from about 1900 to 1915, covers the development and evolution of the heavier type of gasoline or kerosene engine used essentially the same as the steam traction-engine. The third period begins about 1913, and the first phase of this ended in September, 1920. We are still in this particular period, which can be designated as that covering the light gasoline-driven tractor.

The first record that we have of a tractor or road engine is covered by a United States patent issued in February, 1817. This was nearly 10 years before Stevenson ran the first locomotive and railroad train in England, and more than 10 years before the DeWitt Clinton ran first in this Country. Many other patents between 1817 and 1863 covered various schemes for road engines, steam coaches and the like, none of which amounted to anything commercially. The earliest record of a steam tractor having plows attached to it is in a patent issued in 1856. It was not, however, until the Country had begun to recover from the effects of the Civil War, that is, in the 1870s, that any practical application of steam power was made to farming operations.

This first application consisted of utilizing a portable steam engine, such as was being used at that time for operating small sawmills. The engine was belted to a grain separator or threshing machine which, at that time, was being operated principally with horse tread-mills or horse sweep-powers. J. B. Bartholomew, of the Avery Co., says that these portable threshing-machine engines were fairly common in central Illinois in 1879, and that a considerable demand developed among the users for a machine that would be self-propelling. The following year, 1880, several of these self-propelled tractors were brought out. The first ones consisted of a suitable gearing for the rear wheels, and a belt drive from the engine flywheel to the countershaft of this gearing. A tongue was connected in front, and a team of horses was used to guide the rig. That year marked the use of the first

Fig. 1—The Original Wysong & Eason Tractor Pulling Six 14-In. Plows in Buffalo Grass Sod

100 self-propelled steam-engines in the United States, and is therefore taken as the beginning of the steam-engine era of power farming.

The invention and perfecting of a steering-gear, a patent for which was issued in 1880, and later the introduction of a clutch and gear train between the engine and the driving wheels together with a number of detail patents relating to compensating gears, mountings and the like, marked the early stages in the evolution of the steam traction-engine. The main idea of these early designers was to develop a threshing engine that would be able to propel itself and pull a separator along with it from one farm to another. The manufacturers, however, had not much more than perfected the steam engine so that it would do this satisfactorily when the owners in several parts of the Country began hooking plows on behind the engine and attempting to do plowing when they were not engaged in threshing. Some of these earlier attempts merely made use of the horse-drawn walking-plow, and required one man for each plow in addition to two men to run the engine. From this beginning it was only a step to hooking up horse-drawn sulky-plows behind the

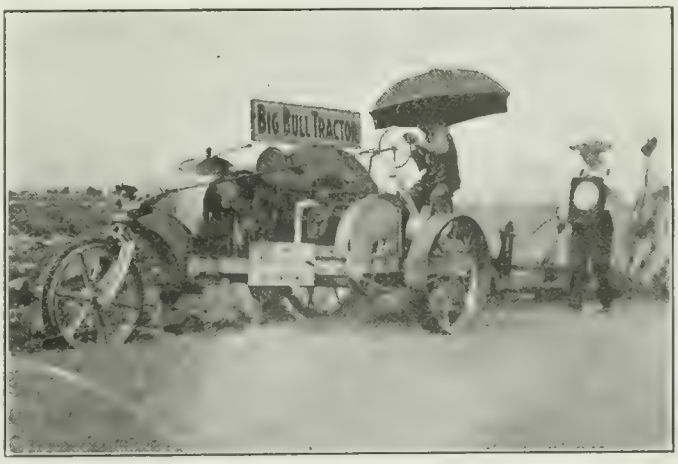


Fig. 2—The Bull Tractor at the 1916 National Tractor Demonstration

[1] M.S.A.E.- Vice-president, Samson Tractor Co., Janesville, Wis

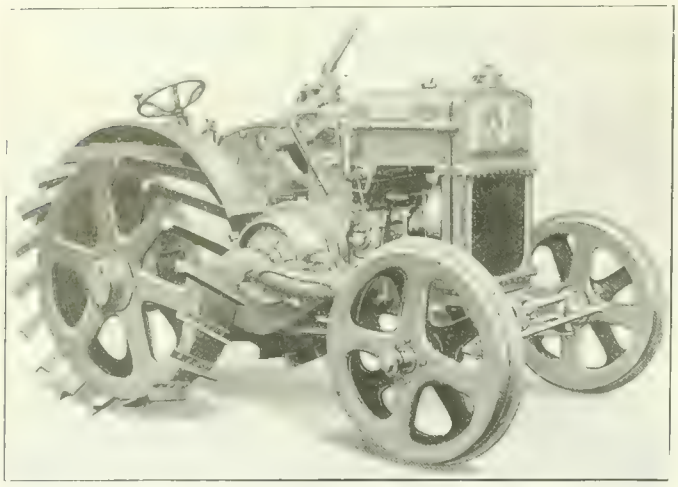


FIG. 3—THE CASE TRACTOR RATED AT 12 TO 20 HP

steam engine and, about 1898, the first special engine-drawn gang-plows were built.

About 1890 to 1892, it was a marvel to see a steam engine plow; and it was then that I saw the first steam plowing-rig in southwest Kansas; but, by 1902, there were 30 steam plowing outfits in Meade County, Kan. Many of these were the largest, heaviest compound steam tractors ever built, and most of them pulled plows made up of an especially heavy three-bottom unit, hitched behind a long beam that was attached to the engine by log chains and steel cables. Two men for the engine itself and usually two or three plow-tenders were required to keep one of these outfits going. Besides this, it required a man and team to haul coal and one or two teams with tank wagons to haul water. I know this definitely because I once had a job on a tank wagon trying to haul water enough to a Reeves compound 32-hp. engine that was pulling 12 plow-bottoms. It also required the services of another man, team and plow to keep the corners plowed out. These big steam rigs worked very well and showed a profit on their large-scale operation so long as they had virgin sod to work on; but, after the ground had been turned up and in wheat for two seasons, they were not so satisfactory for the second plowing, although the use of steam tractors continued for several years after the time of which I speak, and they are in use in some sections even at present.

The production of steam traction-engines reached its maximum about 1910, and has since declined because the field formerly covered by these rigs was taken over by the heavier and larger sizes of gasoline and kerosene-burning tractors. From a maximum production of 14,000 in 1910, steam traction-engine production has dropped until there are probably not more than 500 to 600 made each year at present.

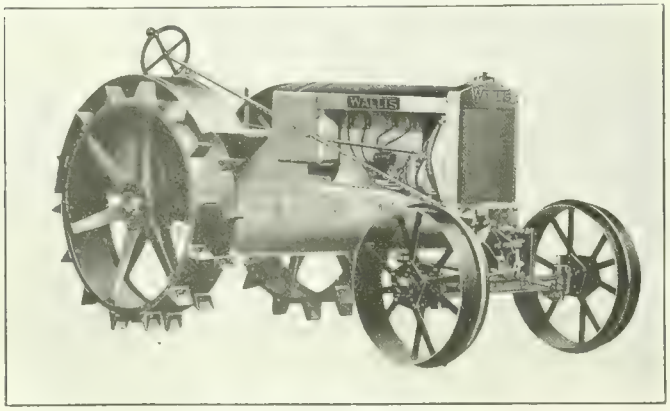


FIG. 4—THE 1923 MODEL WALLIS TRACTOR

INTERNAL-COMBUSTION-ENGINE APPLICATION

The limitations of the steam tractor for plowing work became apparent almost as soon as it was started, and many inventors turned their minds toward adapting the internal-combustion-engine to this class of service. Some machines of this type, making use of a steam-tractor running-gear and a stationary type of gasoline or kerosene engine, were built in 1900. It was not until about 1907 that the first 100 successful gasoline-driven tractors were actually in use in this Country. From 1908 to 1915 the development of the heavy gasoline tractor was extremely rapid, and some spectacular successes and failures are on record covering this period. The first national tractor demonstration held in the United States was at Fremont, Neb., in 1912. At this demonstration the gasoline-driven tractor predominated. There were a few steamers on exhibition, but it was plainly to be seen that the chief interests centered on the gasoline and the kerosene-engine job. By 1913, however, the large-tractor boom had reached its maximum proportion, and 1914 marked the beginning of the end of this era of development. It also marked the beginning of the third era that of the small gasoline-driven tractor.

LIGHT TRACTOR

The ideas underlying these different eras had their inception long before the machines were accepted by the public and, in the same way, the light-tractor idea had been working for many years before it actually was commercialized. In 1903, after my experience in hauling water and swabbing flues for the steam-tractor rigs, I concluded that what we wanted was not a big clumsy outfit for custom threshing and plowing, but a little, light, cheap, versatile tractor that every farmer could own individually and do what he pleased with. Ansel S. Wysong was the chief instigator in developing these schemes. We came to the conclusion more or less jointly that the tractor was our one certain road to fame and fortune. We had not only worked on the steam outfit, but were assiduous readers of technical periodicals and persistent gatherers of catalogs and printed information put out by the early motor-car builders. We therefore felt qualified to design a farm tractor.

We decided that we wanted a machine weighing not more than 2 tons, that would pull three 14-in. plow-bottoms and that could be sold profitably for $750. Our first effort embodied the brilliant idea of dispensing with one rear wheel, and the consequent cost and complication of a differential gearing. We worked out a simple spur-gear and chain drive to connect-up our one drive-wheel with a two-cylinder two-cycle vertical-engine, purchased from the Cushman Engine Co., at Lincoln, Neb. Our first tests with this machine occurred in October, 1904, in a potato field near Topeka, Kan. We were out in the field for 2 days, and then decided that one drive-wheel was not sufficient; consequently, we made the job over. Using the same engine, we built an additional rear wheel, got a differential and some more chain and provided a single steering-wheel in front, mounted on a turnable arrangement. We finished the job that winter and, by the spring of 1905, had it down in our southwest Kansas home for a practical tryout on a farm. We had determined previously, by using a home-made dynamometer, that only 300 to 400 lb. drawbar pull was needed for one

14-in. plow at the depths ordinarily plowed in southwest Kansas; that is 3 or 4 in. We figured it was mere boys' work to determine that a 15-hp. engine was much more powerful than would be needed to propel a 4000-lb. tractor and draw three 14-in. plows behind it. However, when we got this machine out in the field, the best we could do was draw two plows, and those not any too well. We did, however, plow about 40 acres that spring and double-disced 120 acres, seeding it to barley in a third operation. At harvest time we purchased a 6-ft. binder and, by using two operators, cut the entire 120 acres of barley with a reasonable degree of satisfaction; but only

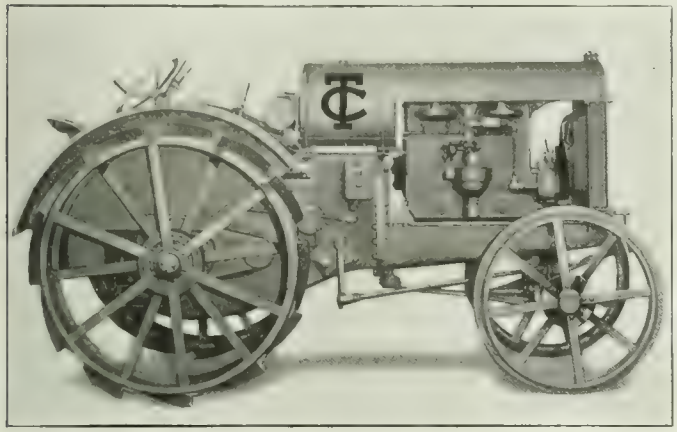


FIG. 5—THE TWIN CITY 12-20 HP. TRACTOR

by much night work to keep the machine in running order. We later put on a two-cylinder apposed four cycle engine, made by the Brennen Engines Co. This had about 20 hp. and pulled three plows very satisfactorily. At one time just for a stunt we pulled six 14-in. plows with this rig, as shown in Fig. 1.

When we tried to organize a company for the construction of the tractor, we found that we could not interest

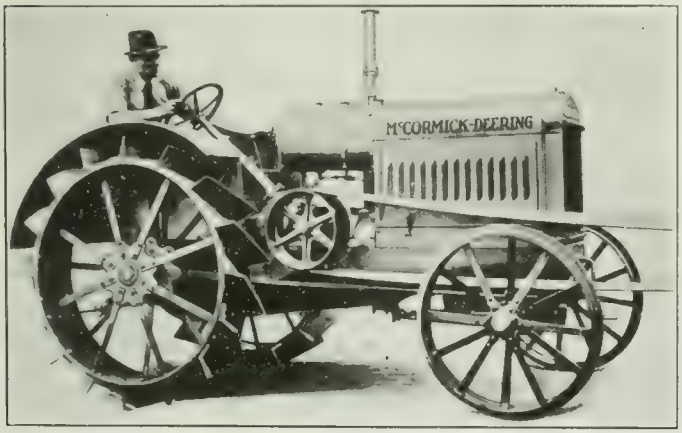


FIG. 6—THE MCCORMICK-DEERING 15-30 HP. TRACTOR

anyone in our project unless we agreed to make a "real" tractor that would pull 10 or 12 plows; consequently, we agreed to make one. But we failed after two years of heartbreaking work, simply because we did not have technical knowledge enough to carry our designs through to a final conclusion.

The first machine to be put on the market in any significant quantities was the Bull tractor, which was started in a small way about 1912, but was really not heard of

FIG. 7—THE AVERY 15-30 HP. TRACTOR

until it took the Country by storm in 1915. Several thousand of these tractors were built in the original model, illustrated in Fig. 2.

The commercial success of the Bull tractor had a tremendous influence on the tractor industry and, by 1916, there were 165 different companies in this Country attempting to duplicate its success with the small tractor. In my paper on the Farm Tractor,[2] presented before the

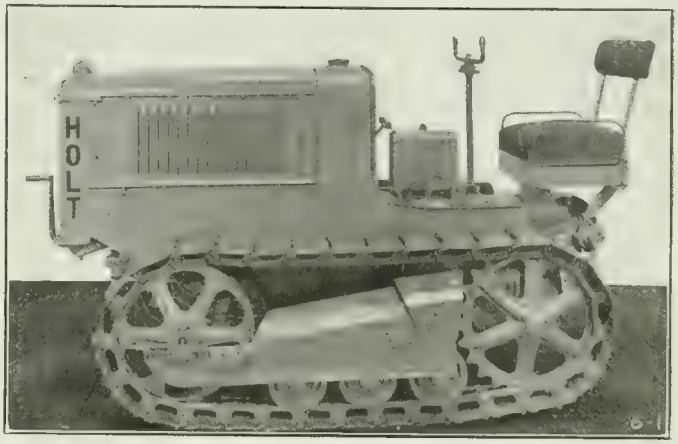


FIG. 8—THE HOLT T-35 TRACTOR

Society in 1916, I gave a résumé of the tractors then on the market. It is interesting to note that, of the 32 machines that I selected to illustrate this presentation, only three are on the market today, unchanged from their original form, except for detail refinement and improvement. These are the Rumely, the Avery and the Aultman-Taylor, all of the large type laid down originally to take the place of the steam threshing-engine. Four or five others of the machines presented at that time are very nearly the same now as then; these are the Lauson, Waterloo Boy, Avery 8-16, Gray wide-drum drive, and Holt 45 caterpillar. Changes from the originals of these models are sufficient to call them new machines, but they

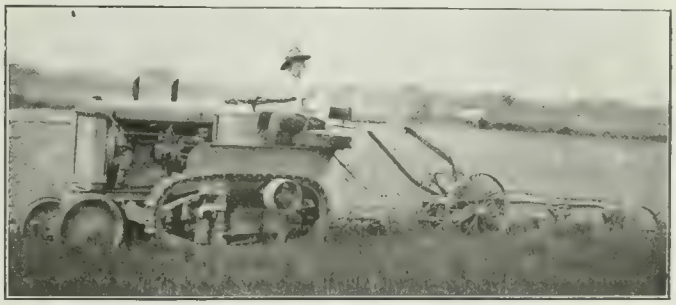


FIG. 9—THE AVERY TRACK RUNNER TRACTOR

[2] See TRANSACTIONS, vol. 11, part 2, p. 363.

FIG. 10—CULTIVATING CORN WITH A POWER CULTIVATOR HAVING A TRIANGULAR ARRANGEMENT OF THE WHEELS

are practically the same design as formerly. All of the other machines shown 7 years ago are extinct.

In the place of the heterogeneous constructions of 1916, there has arisen during the past few years, and more particularly in the last three years, a very decided acceptance of the two-rear-wheel drive, four-wheel type of tractor as exemplified by the Fordson, Wallis, Minneapolis, the new I.H.C. 15-30 and the Avery 15-30. The caterpillar type of tractor has also come to be accepted as meeting the requirements for a special machine, particularly on commercial work such as road building and the like. The modern line of Holt machines, the 10-ton, 5-ton and T-35 models, brought out since the war the new Avery Track Runner and the latest Bates Crawler Drive are representative of this type of machine. Figs. 3 to 9 inclusive show this evolution.

POWER CULTIVATORS

It is rather difficult to say whether the general acceptance of the conventional tractor is due to the fact that this is inherently the best type of tractor for farm use, or whether the spectacular commercial success of the Fordson tractor has not served to crystallize the type more than any other one factor. Whatever the reason, the light tractor that shows clearly the effects of automotive engineering does predominate, and has been accepted as standard and conventional by the farming public. Everyone, however, with the possible exception of Mr. Ford, is ready to admit that the conventional type of tractor has its limitations and that all the farm work on all the farms all over the United States cannot by any means be accomplished by the four-wheel, rear-wheel-drive type of tractor as made at present. That it performs its functions effectively and efficiently, within the limitations of its type, cannot be questioned. As a drawbar power-machine for plowing and discing, these tractors are very successful and within the limit of their engine capacity they are very satisfactory for belt work. There is a decided tendency toward individually owned small grain separators, ensilage cutters, wood saws and the like, and these lighter tractors of the two and three-plow capacity take care of this kind of machinery in good shape. On the diversified farms, where row crops as well as small grains are raised, there are actually more hours of work per year to be done in cultivating and in the numerous odd jobs now taken care of by horses, than there are hours of work at plowing, discing or belt work. This condition is summed up very neatly by the United States Department of Agriculture[3] as follows:

> The construction of most four-wheel and crawler-type tractors is such that they are not satisfactory for cultivating corn. When such a machine is bought, the number of horses that will be necessary to retain is the maximum required for the cultivation of corn and for other work coming at the same time....If the corn is to be cultivated with horses, it will usually be necessary to retain at least one horse for each 20 acres of corn.

These facts, which are fairly well recognized by most tractor builders, have led to the development of a considerable variety of motor cultivators intended to supplement rather than replace the conventional tractor on the corn-belt farms. Everyone familiar with the industry knows the relative importance of row crops to the small grain crops of the Country, and is therefore keenly alive to the necessity of developing machines that will take care of the work that must be done effectively and efficiently. Building a power cultivator is as different from building a light tractor as a light tractor is different from a heavy tractor. The problems to be solved in the power cultivator may appear easy at first glance but, after one gets into the subject, there seem to be many limitations of an entirely unsuspected nature. Tractor engineers have had the problem in mind for a long time, but it was not until about 1917 that power cultivators, as such, were offered to the public by responsible manufacturers. Some of these earlier machines are typified by the Avery, Bailor, Emerson-Brantingham, Rock Island and Parrett cultivators. All of these were three-wheel machines; that is, they had their wheels disposed in a triangle, with one wheel between the center corn rows and set ahead of the driving wheels, which were between the outside corn rows. They all carried two-row cultivators, and were recommended for cultivating only. Fig. 10 shows this type of power cultivator.

For some years prior to 1918, William Springer was working on the problem of power cultivation and developed a machine that he called the Jim Dandy. This was a four-wheel-drive affair with a very short wheelbase and a very wide tread, relatively. It was steered the same as a Muley-type caterpillar; that is, by changing the speed of either set of wheels, by declutching and applying a brake to the side around which it was desired to turn. Mr. Springer used a belt drive on his original machine because this gave him a very simple forward and reverse control and the belts also served in the place of clutches by using a belt tightener or idler to apply tension. In the original machine built by Mr. Springer, there was no intention of carrying the development beyond a simple light cheap power-cultivator, for utilizing a two-row cultivator and a corn-planter attachment, the latter arrangement being illustrated in Fig. 11. The idea was purchased from Mr. Springer by the General Motors Corporation in 1918, and some further development work was done on the job with the idea of making it a universal or general-purpose machine. It was christened the Samson Iron Horse and some 1500 or 1600 of the machines were built according to the revised design and distributed to farmers. It was found, however, that there were certain mechanical limitations to the design and some inherent difficulties with the belt drive which, for a general-purpose machine, made the scheme undesirable; consequently, it was abandoned.

Another machine that belongs in the two-row-culti-

[3] See Department of Agriculture Bulletin No. 1296 (1924) of Washington.

vator class is the Toro. In this machine, the driving wheels are set ahead of the cultivator shovels and pivoted, with a universal-joint drive so that they can be steered. The drive-wheels are set two rows wide, and the third point of support is behind, between the center rows. For straight going down the corn rows, the trailing wheels are locked in position and all steering is done by the leading drive-wheels. When the end is reached the trailer wheels are unlocked, are allowed to swing free and a differential brake is applied to the inside drive-wheel; whereupon, the whole rig turns around one wheel and is ready to come back in the adjacent corn row. It is claimed that there is a considerable advantage in the additional flexibility of the unit when built in this manner and, further, that there are many other operations that can be done successfully with this type of machine around the farm. In addition to handling cultivator shovels of all sorts, and there is an infinite variety of these to be taken care of, this machine is arranged to operate a middle buster or corn lister and, due to the spacing and arrangement of the wheels, it takes care of this operation very satisfactorily. A two-row corn-planter attachment has been applied to the machine and also a mowing-machine cutter-bar. With these different attachments, the Toro cultivator merges into the general-purpose type of tractor. Two views giving some idea of the versatility of this machine are reproduced in Fig. 12.

In summing up this subject of the conventional type of tractor supplemented by a motor cultivator, it would seem that the combination is thoroughly justified for corn-belt farms of more than 160 acres, and is one that will be maintained for many years to come. Table 1 submitted through the courtesy of the Avery Co., shows what can be done on a large corn-belt farm, operating on the recommended three-year rotation basis, with 120 acres of corn and 60 acres of oats for each year's crop. The time is figured on the basis of a three-plow tractor for plowing and discing, and a two-row cultivator for planting, harrowing and cultivating corn. The time required for the different operations and the date at which these operations must be carried out to be most effective in central Illinois are stated in Table 1.

Table 1 gives a total of 61 days for *one man*, spread over a period of 3 months and 10 days, and brings both the oats and corn up to the time of harvest. If this method, which is entirely possible, is contrasted with that usually employed for the same acreage, using men and horses for all of this work, it will be seen readily that there are both an advantage and a profit in doing the work with the tractor and the cultivator. To duplicate this using horses, instead of tractors, would require three or four men to accomplish the same amount of work as one man can do with the motorized equipment.

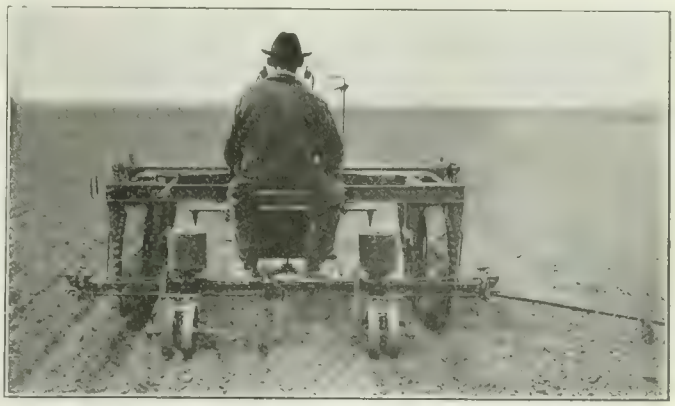


FIG. 11.—A TWO-ROW CULTIVATOR AND CORN-PLANTER COMBINATION

TABLE 1—THREE-PLOW TRACTOR AND TWO-ROW CULTIVATOR WORK REQUIRED ON A 160-ACRE CENTRAL ILLINOIS FARM

Date	Kind of Operation	Time Required, Days
April 1 to 7	Double-disc 60 acres, four-row	3
April 1 to 7	Drill-in 60 acres of oats	3
April 17 to 30	Plow 120 acres for corn	12
April 24 to 30 or May 1 to 7	Double-disc and harrow the plowed ground in one operation	5
	Total time, three-plow tractor	23
May 8 to 14 or May 15 to 21	Plant corn, using motor-cultivator and corn-planter attachment	7
May 25 to 31	Harrow after planting, using motor-cultivator and peg-tooth harrow covering four rows	4
June 1 to July 10	—Cultivation:	
	First	8
	Second	7
	Third	6
	Fourth	6
	Total time, motor-cultivator	38

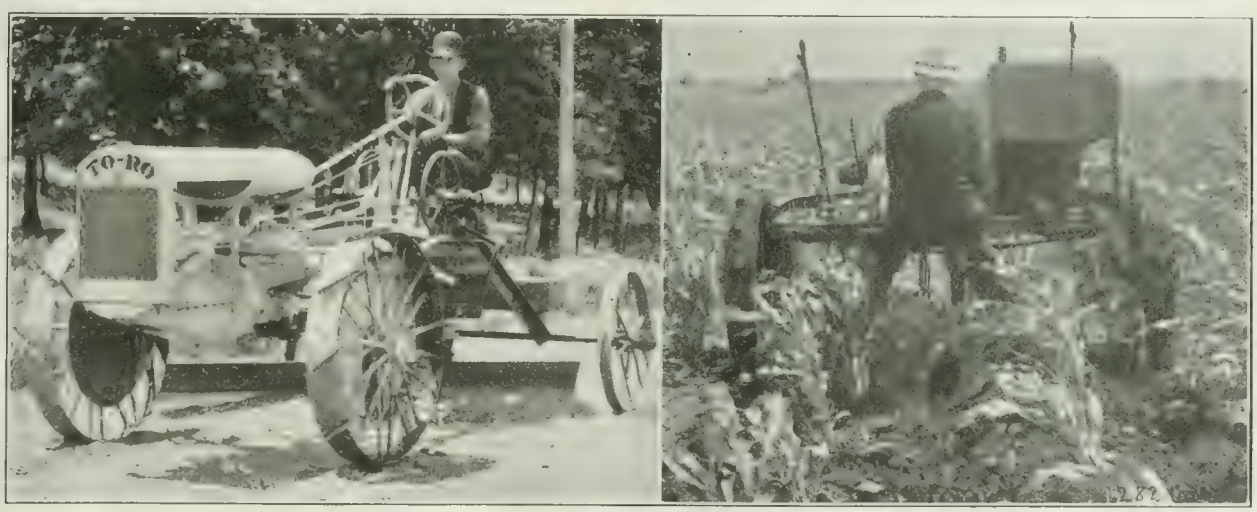


FIG. 12.—TWO VIEWS SHOWING THE VERSATILITY OF ONE TYPE OF TWO-ROW CULTIVATOR

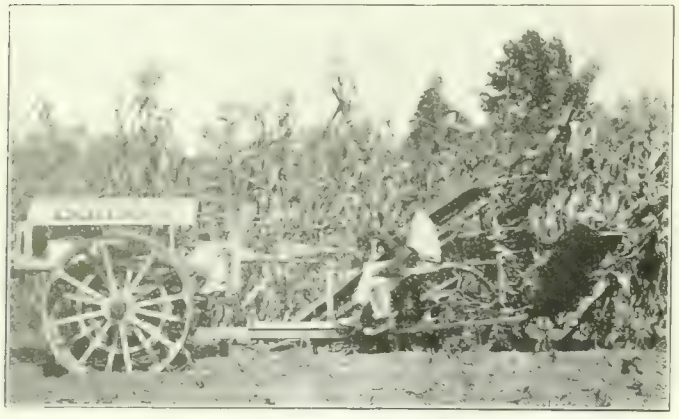


Fig. 13 — A Tractor Equipped with a Corn Binder

Since the corn, hog and cattle combination has proved to be a more profitable method of farming than to specialize on grain alone, the three-plow tractor and the motor cultivator on farms large enough to support the investment is a labor-saving combination, and already has proved profitable to farmers who have been doing their work in this manner.

General-Purpose Machinery

There is some question as to whether farms of less than 160 acres can be made profitable, but the fact remains that more than one-half of all the farms in this Country are in quarter-section sizes or less. While many of these quarter-section farms could, because of favorable location and good management, support the investment in a three-plow tractor and two-row cultivator, it is doubtful if this much equipment would prove profitable throughout the Country as a whole. There is, therefore, a considerable volume of business to be had for a machine that will farm the smaller units, averaging 100 acres per farm, profitably.

Recognizing this potential market, many attempts have been made to combine in one machine the ability to both plow and cultivate and do as many other of the farm operations as may be possible, with one power-plant. A tractor designed along this line is usually called a general-purpose tractor. The machines in this class that have already been put on the market can be divided into three general classes, with some minor variations. First, the two-wheel front-drive, of which the Hoke, Moline and Allis-Chalmers are representative. Second, the crawler type, such as the Bates, Bean Spray Pump and Cleveland. Third, the four-wheel straddle type with a high center clearance, such as the LaCrosse Model M, the Parrett Cultor and the Rock Island plow tractors.

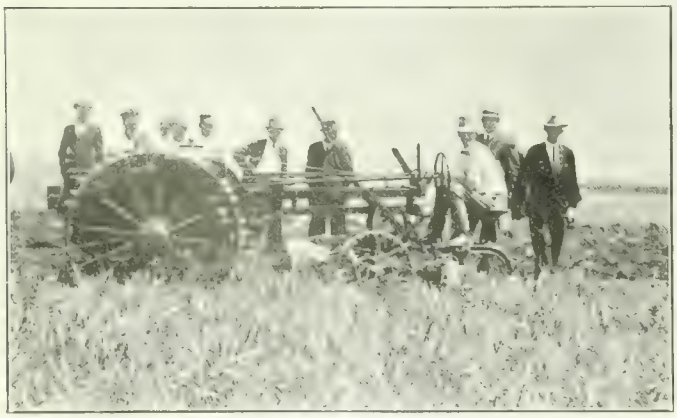


Fig. 14 — The Funk Cultiplow That Was Exhibited at the 1917 Tractor Demonstration

The Hoke tractor was one of the earliest attempts to combine in one tractor the ability to handle all farm implements pulled by two or three horses. The first of these were built privately in 1912 and 1913. This tractor is now known as the Indiana and is shown in Fig. 13 at work binding corn. The following is quoted from a letter received March 13, 1923, from the Indiana Silo & Tractor Co.

> This tractor is constructed on the theory that a tractor to be an economical proposition must more thoroughly replace horses than does the ordinary four-wheel type. It is possible with this construction to handle every crop operation on a corn-belt farm, or even on a cotton-belt farm, without the use of horses. ....We wish to call attention also to the fact that the tractor is used with the ordinary farm implement which the farmer has been using with horses, so that no extra farm equipment is necessary with this tractor, except a plow. We have customers operating 160-acre farms completely with this tractor and a single team of horses, the horses being used for whatever wagon work is necessary, but not on the crop operation. We have about 1600 of these tractors in the field.

There is some question as to whether Mr. Hoke or T. B. Funk was the first to experiment with the two-wheel front-drive type of machine. Both men, working independently, arrived at about the same conclusion. Mr. Funk's experience is rather interesting. His first tractor was built of a pair of mowing-machine wheels and the engine from his motorcycle. He provided the job with a pair of plow handles, the idea being that a man could walk along behind and guide the machine and the cultivator shovels or plow. So far as is known, this particular machine antedates all of the so-called garden-tractors, a considerable number of which are now on the market. Mr. Funk says:

> The first machine was built down at Yukon, Okla., and was made up of a motorcycle engine and some mowing machine wheels and a little bicycle chain and some sprockets. The object was to determine whether the thing would work and if not, why. No data were available relative to drawbar requirements, the horsepower needed or anything else, for that matter. The cobbled-up job seemed to "point the way," so * * * I came up to Indianapolis and laid down a paper job with a motorcycle engine but with the worm drive and a regular transmission system all enclosed This job proved to be too light to do much work. However, it was easily steered and by that I mean comparatively easy, but it was not strong enough. When we made it more powerful and put in enough weight to utilize the power it became too heavy to steer manually. The natural thing to do then was to change the steering, and in this development it soon became apparent that the operator might as well ride as not, so we put him on the implement because there was no room for him any other place.
>
> The second machine was an air-cooled engine, the third a single water-cooled cylinder and the fourth a twin V engine. The fifth, which was the Cultiplow shown in Fig. 14, was a two-cylinder opposed engine, and the sixth the four-cylinder job as it is now made by the Moline Plow Co.

The Allis-Chalmers Mfg. Co. also makes a two-wheel front-drive tractor, illustrated in Fig. 15. Its machine, however, is considerably lighter than the Moline tractor and differs from it principally in details of construction. An experiment that J. F. Max Patitz of the Allis-Chalmers Co. tried is rather interesting. This consisted of

taking two of the regular jobs, hitching them together back to back, as shown in Fig. 16, and driving them in one direction as a single unit. In this manner it was possible to get a machine that one man could operate and that was capable of pulling a three-bottom plow under ordinary conditions; otherwise, it would take two men and two single-bottom 16-in. plows. There is possibly an idea in this experiment that is capable of further development. There is no particular difficulty in getting two separate engines to operate together and, if one started out with the idea of making a two-engine four-wheel-drive tractor capable of being broken-up into two units, each of which could be used for cultivating, the result might be a very satisfactory solution of the farm-power problem. It would at least follow along the line of present practice with horses, where five or six horses are used on a two-bottom plow and only two horses on a single-row cultivator.

Cultivation Obstacles

S. L. Allen & Co., Inc., of Philadelphia, also did much work with the two-wheel front-drive type of tractor, designed for cultivating and plowing. Although their experience resulted in their deciding to give up the idea, so far as they themselves are concerned, their conclusion as outlined in a letter from C. J. Allen, is of interest.

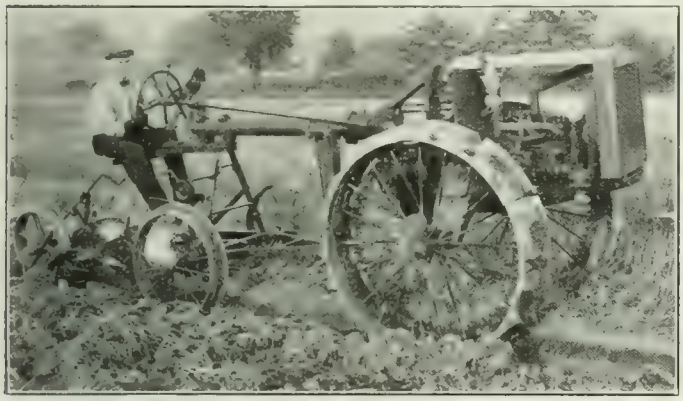


Fig. 15—A Two-Wheel Front-Drive Tractor Pulling a Two-Bottom 24-In. Disc Plow

> Our original idea in building a tractor was to design and manufacture one that would primarily be a cultivator, not too large nor too small, nor too cheap, and handle the large row crops, such as corn, potatoes, beans, beets, etc. After analyzing the situation the two-wheel type seemed to have the best possibilities as a cultivator unit and at the same time the advantages of being adapted to plowing, discing, fitting, seeding, harvesting, hauling, etc. From the endless number of jobs such a machine could accomplish, it appeared to us it would make an ideal one-man general-purpose tractor and take care of all the work on small farms from 25 to 75 acres; and, in addition, be right for light work on any large farm for the same purposes. With the wheels adjustable to 36, 40 and 44 in. to give as much plant clearance as any light-weight tractor of 2600 lb. with wheels 44 in. in diameter and a 7-in. face, a reasonable turning radius, a Le Roi engine and Hyatt bearings throughout, combined with a single and double-row cultivator, the job looked very easy. In addition to these features the market for this type was large and the cultivating not unlike that of the past.
>
> Our tractor, which is illustrated in Fig. 17, was developed with the assistance of the Hyatt Roller Bearing and the McVicker Engineering companies in a very neat and complete form and apparently was capable of accomplishing everything on the farm. Plowing proved easy under favorable conditions; in sandy soil not so good; in hard clay there was scarcely enough power, and on slight grades or poor traction a failure.
>
> The plow was not all that could be desired. It was difficult to hitch up properly and dangerous for the operator's feet when it lifted out of the furrow, and it required a number of depth adjustments throughout the field. If the wheels of the plow were larger and had wide tires the discs and harrows could be attached to the rear of the plow and the ground fitted for seeding without making any change. The present weight of the plow and the operator, combined with the thrust of the tractor beam, made the above hitch impracticable. Removing the plow and replacing the rear carriage on the tractor is hard work and requires two men to do the work satisfactorily. If all the plowing, fitting and seeding could be done without any change of the plow considerable time could be saved while putting in the crops. In some cases, of course, it might be necessary to put the cultivator on before all the ground was seeded. If plowing was all finished the cultivator would answer as a carriage for discing and preparing the seed bed, as the tool bars could be removed if in the way.
>
> Our principle of two-row cultivation has always been to straddle and cultivate thoroughly the center row and finish half of the row on either side. This is practical when two and four rows are planted at a time and has the advantage that it can be used as a one or two-row cultivator by removing the outside teeth, which is very helpful in early cultivations. The same principle was followed out in the power cultivator, with the exception that the pivot wheels were omitted. This added complications, as it was necessary to float the tool bar from side to side at least 6 in. and at the same time be able to expand and contract the outside tool bars. This increased the expense and was not entirely satisfactory, as it was not so easy to accomplish when the tractor was in motion and the teeth were in the ground. The

Fig. 16—A Duplex Tractor Made Up of Two of the Units Shown in Fig. 15

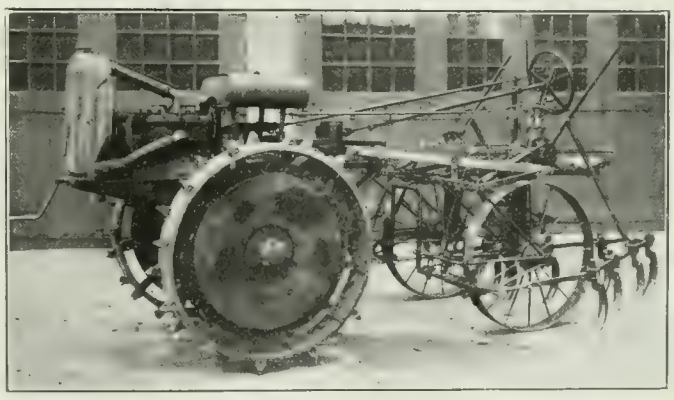


Fig. 17—A Two-Row Front-Drive Tractor and a Two-Row Cultivator

Production of This Machine, Which Was Developed as a One-Man General-Purpose Tractor To Handle All of the Work on Farms Ranging from 25 to 75 Acres in Size Has Since Been Abandoned

single-row cultivator would not require the expander levers. It would therefore be cheaper and we think that it is the best cultivator for the average small farmer.

The special four-row beet machine, suitable for rows spaced from 20 to 24 in. apart, proved to be the best combination. Two acres per hour were satisfactorily cultivated when traveling at 3 or 3¼ m.p.h. The steering was easy and accurate, even when the hoes were set as narrow as 4 or 5 in. apart; in fact, the higher the speed the easier the guiding of the tractor and the cultivator. This accuracy was only secured after offsetting the seat and placing a pointer over the row. This arrangement gave an extended view of the row and watching the pointer gave the operator the exact location of the tractor.

Cultivating corn and potatoes was much more difficult. Deeper cultivation made the gangs harder to steer and the heavier drawbar pull made the tractor more headstrong. When the crop is small it is necessary to watch under the machine, and more accurate work could be accomplished by offsetting the seat and applying a marker under the tractor to point at the row. Under the most favorable conditions the driver had a busy time to do good cultivating. In the later cultivations the guiding proved easier, as the teeth were set wider apart.

The steering gear of the tractor should have little lost motion, so that the wheels can be held and driven like an automobile. Half a turn of the steering-wheel should be sufficient for guiding the machine down the row.

Faults or features that might be improved upon are as follows: This type of tractor is necessarily built high to get enough clearance. This makes the machine too high to see over, not high enough to see under and too wide to see around.

At best the tractor is hard to drive straight and keep over the row, and this is the secret of all good cultivating. Drive the tractor right and the cultivating will take care of itself. There are three chances to one of getting off the row when operating a tractor, one chance to the right, one to the left, and the third from side-slipping on hillsides or overloads. The moment one wheel slips more than the other this steers the machine out of the row. The last point, together with a little lost motion in the steering arrangement, seems to make the two-wheel tractor somewhat of a "wanderer," and as it has no horse sense to help out, the moment the thoughts of the operator wander the tractor does likewise.

Turning with this type of machine is rather slow and hard work if the right cultivating ratio is used on the steering-gear. To overcome this we designed a two-speed steering-gear, one for cultivating and the other for turning. This appears to us to be a necessary feature. Small farms seldom have headlands large enough to turn without backing. The customary way of skipping a few sets of rows, as is done with a team, should be followed by the tractor driver.

Fields with low land or wet spots also cause trouble. Sand is no place for a two-wheel tractor; neither are slight grades, which the farmer counts as level ground. The width of the wheel setting has considerable to do with the drawbar pull delivery. If possible the rear carriage should be eliminated and the cultivator used for this purpose, thus avoiding extra changes.

The term "one-man" tractor is a misnomer, as it is not practicable for one man to change implements weighing 400 to 700 lb. The sales argument that all the machinery now on the farm can be readily and satisfactorily attached to the tractor does not agree with our experience. Two-wheel tractors should balance when the beam has nothing attached, or a slight overweight in front will do no harm.

To size up the situation from our standpoint it would seem that there is room for great improvement on this type of machine, and although the field is large and the machine can be applied to numerous jobs, we think there are other types of tractors that are better from the cultivating standpoint. The development to date seems to prove that the single-purpose tractor cultivator has made the best progress so far. There is still a difference of opinion regarding these machines, as some have a steering caster wheel in front and rear drive, while others have the front steering drive with a caster wheel in rear.

It would seem that the general-purpose tractor is decidedly on the wane and that the tractor which is made up for one or two kinds of work will be more satisfactory and have a better sale than a machine that is supposed to do everything on the farm with all the old machinery that may be at hand, but not do any of it well. It seems to us that the horse will always have a place on the majority of farms, although there are some types of farms that can be completely motorized to advantage. The fact that the farmer tries to do the most difficult operation on the farm with a tractor is the cause of a number of tractor failures. What the farmer should do is to plan his farming so that the tractor gets the job for which it is best adapted and saves the most, and let the horse take care of the odd and more difficult ones.

Crawler Type General-Purpose Tractors

One of the early attempts to break away entirely from the conventional tractor and to combine in one high-power machine, the ability to handle all of the horse-drawn implements was made by the designers of the Bates Steel Mule that was placed on the market first in 1915, H. H. Bates says that they started with the idea of building a machine that could be used for every essential operation on the average 160-acre farm. This, of course, included plowing, planting and cultivating corn, as well as seed-bed preparation and harvesting of small grains and a sufficient amount of power for belt work, small grain separators, silo fillers, feed mills and the like. The idea was to produce a machine that could be used every time power was required, every day in the year. In the 3 or 4 years that this machine was on the market, several thousand were sold and a large percentage of them are still in use at present. I have always considered that this machine had some very strong fundamental advantages but, like everything of the sort, it also had its limitation. A view of one of these tractors breaking prairie sod is shown in Fig. 18.

As to this, I quote from a letter recently received from Mr. Bates, as follows:

> Being like a three-legged milk-stool, it would get a streak and lie down on its side now and then, whenever the ground was too rough. However, I do not believe it is any more bulky than the Fordson tractor, which has a tendency to roll back on its ears whenever it feels a little temperamental. It was a little awkward to turn around in the cornfield but, at that, it did not knock down any more corn than horses ordinarily do. As a matter of fact, where the land was nearly level, this tractor could do more work with one man than anything that we have ever seen. There was one big drawback, and that was the fact that it looked so different from the usual run of tractors. The farmer had to have a strong imagination and a will of iron to buy it in spite of his neighbor's opinion. Other tractor salesmen would come around and talk to him and after about 10 of them, following one after the other, pointed out to the farmer the difference between the conventional tractor and the one that we were trying to sell him, he had to be the kind of a fellow

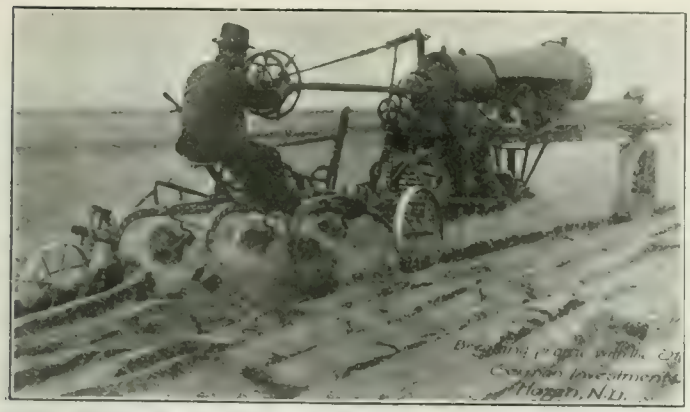


FIG. 18—THE BATES STEEL MULE TRACTOR BREAKING PRAIRIE SOD This Tractor Was First Placed on the Market in 1915 and Its Production Ceased in 1918

who, watching a regiment go down the street, saw everybody out of step except his own son Jim.

OTHER TRACTOR TYPES

The Bean Trackpull, which also made use of a single crawler, was built about the same time as the Bates Steel Mule. The design was originated by Alfred Johnson, whose tractor experience goes back to the earliest days of the industry, having designed the Toe-Hold that was built originally by the Joshua Hendy Iron Works in California and, in the early days of the Rumely boom, purchased by the latter company. Mr. Johnson's little single crawler job was built by the Bean Spray Pump Co. of San Jose, Cal. The latest model was shown at Wichita in 1919. Instead of having the steering-wheels ahead as

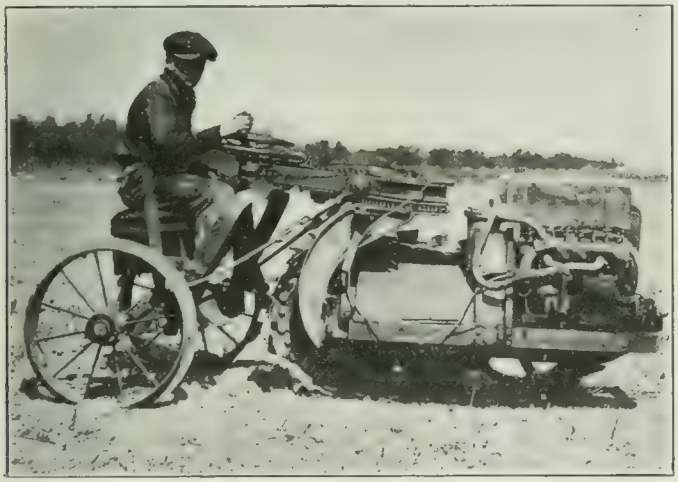


FIG. 19—THE 1917 MODEL OF A SINGLE-CRAWLER TYPE TRACTOR IN WHICH THE ENTIRE POWERPLANT WAS TURNED IN STEERING

in the Bates Steel Mule, this job turned the entire powerplant somewhat the same as the Moline or other front-wheel-drive machines. One of these machines is illustrated in Fig. 19.

At about the same time that the Bates and the Bean tractors were brought out, some experimental work was done on a little tractor that, it was believed, would combine some of the advantages of the Moline and of the crawler drive in one machine. The job was made 30 in. wide overall and was intended to go between the corn rows, using a standard two-row horse-drawn type of cultivator to be operated from the seat of the implement the same as when using horses. Having an endless track, the machine was stable fore and aft, and the implement was subjected to no reaction on account of down-thrust on the rear end. The channel bars extending to the rear were a sort of rudder, since the entire powerplant had to be swung around a pivot for directional control; they also served to carry the steering-wheel and the clutch and the gearshift levers, as shown in Fig. 20. The tractor was driven by a $3\frac{7}{8}$ x $4\frac{1}{2}$-in. four-cylinder vertical-engine, and weighed complete just under 2000 lb. without water, oil or gas. Dynamometer tests showed a satisfactory sustained drawbar pull of 1700 lb. in ordinary stubble-field plowing, that is, where the ground was in normal condition for plowing and not slippery on the surface. It would pull a regular two-bottom 14-in. plow and,

FIG. 20—AN EXPERIMENTAL TRACTOR IN WHICH THE OPERATOR RODE ABOVE THE IMPLEMENT ON A CHANNEL-BAR EXTENSION AND CONTROLLED THE POWERPLANT THROUGH TWO LONG LEVERS AND A HANDWHEEL

under an actual plowing test, showed a remarkable gasoline economy. As a cultivating proposition, however, it was too much of a strain on the operator to watch the machine and the corn simultaneously. It was possible to cultivate with the rig, and much actual work was done with it but, had these ever been built, I am afraid they would have proved to be man-killers in the field, because there was not latitude enough for the front end. On paper, a clearance of 6 in. on each side appears ample but in the field, especially after the corn grows up a little, there seems to be no room between the corn rows for a machine 30-in. wide. The job had another limitation, due

FIG. 21—A COMBINATION OF TRACTOR AND TWO-ROW CULTIVATOR THAT IS CONTROLLED THROUGH THREE LINES, TWO FOR STEERING AND ONE FOR OPERATING THE CLUTCH

to the narrow width; it would lie down if the operator was absent-minded and let the tractor get into a furrow on one side. Being light, it was not much of a trick to get it and probably, after an operator got accustomed to the machine, this would not happen very often. This job was purely experimental and work on it was dropped in 1917 on account of the war. I mention it principally because it shows what is possible along this particular line.

The Cleveland Tractor Co., in addition to its first three-plow model, has brought out a smaller machine comparatively recently and has designed a number of special implements to be fitted to this tractor for cultivating and other special jobs. My opinion is that, in putting the cultivator shovels ahead of the tractor, the Cleveland people have placed them in the most advantageous position for this type of machine, and that it is possible to carry out a satisfactory development along these lines. I have noticed, however, within the past several months, that a new development has been announced. This consists of the small Cletrac with the American Seeding Machine Co.'s two-row cultivator hooked-on behind; the tractor is arranged with a pair of lines for controlling the steering and a third line provided for operating the clutch. Evidently this scheme has been thoroughly tried out and future developments along this line will be followed with considerable interest. It perhaps indicates a tendency toward using lines for tractor control, leaving the operator on the seat of the implement instead of riding on the tractor. A view of this combination is given in Fig. 21.

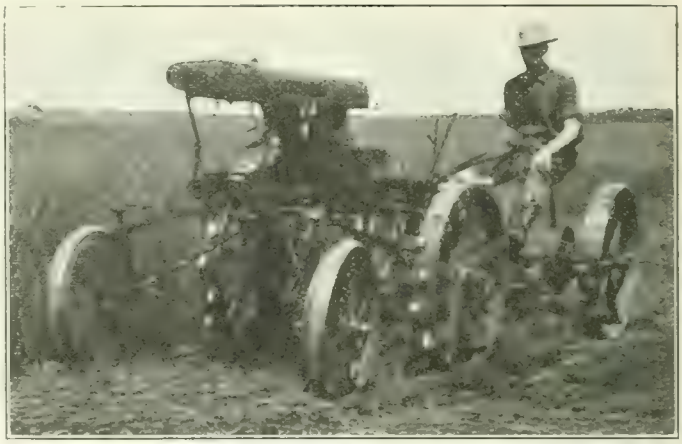


Fig. 24—The Parlett Experimental Four-Wheel Line-Control Tractor Pulling a Mowing Machine

variety of work that can be handled by this machine is brought out in Fig. 22.

L. W. Melcher, who was chiefly responsible for the design, has written as follows regarding his experience with the machine:

> During the early development of farm tractors not much attention was given to the diversified uses to which they might be put. They were constructed primarily to pull plows and tillage implements of the larger sizes, with little consideration given to the possibilities for a greater field of usefulness. The writer attempted to analyze the possibilities of a more general-purpose machine, and the research work which we did resulted in the following ideas:
>
> First, that a general-purpose tractor must be adaptable to all of the work which has to be done on a farm. Through the cooperation of the farmers and the implement manufacturers over a great number of years, it has been possible to perfect a line of implements which are satisfactory for the tilling, cultivating and harvesting of the various crops which are being produced by the American farmer. We started out with the theory, and still believe that we were right, that a tractor should be built to operate the present tools, rather than attempt to build a tractor first and then the tools around it. We hoped by this method of construction to profit by the many years of development which have gone into farm tools. It did not appear reasonable to us that a producer of a new type of implement would be able to develop it to as high a degree of perfection as the line of tools which had already been developed. There is no question that such an improved line could be developed, but it would take a great many years of practical use to prove that this new line would be an advantage over the existing type. Further, it would require the purchase, by the farmer, of an entire new line of tools developed for use with a tractor. It would necessitate an initial investment for a great quantity of additional equipment. We therefore concluded that the best policy would be to construct

Fig. 22—Another Line-Control Type of Tractor Performing a Variety of Operations
At the Left the Tractor Is Shown Pulling a Manure Spreader, in the Middle a Two-Row Cultivator and at the Right a Binding Attachment

Utilization of Existing Farm Equipment

The LaCross Model-M tractor, shown first, I believe, at Wichita, in 1919, is another of the strictly general-purpose type of tractor that have been designed to do all of the farm work and to utilize existing horse-drawn equipment. The mechanical details of this machine are probably very well known, the engine being a two-cylinder horizontal type with a ball-bearing crankshaft, and an internal spur-friction type of drive. An idea of the

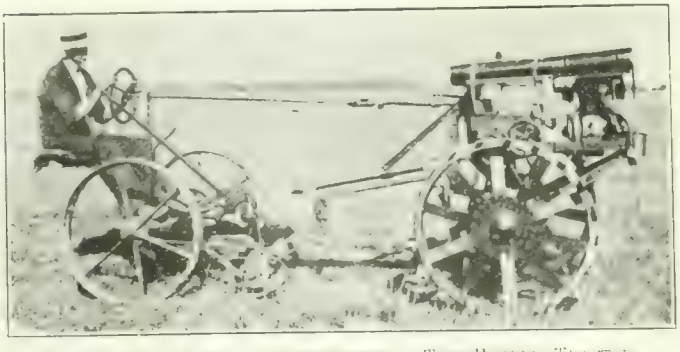


Fig. 23—The Parlett Experimental Two-Wheel Tractor Pulling a Mowing Machine

simply a mechanical team of horses, which would replace the animals now in use in every way possible, but which would operate at a greater speed and with more economical results.

The size of the tractor should be comparable with that of the implements which are now in use. Our investigations led us to believe that the average farm which could successfully use this type of tractor is, at present, using 5 horses constantly. The farmer may carry a reserve number but he would not use at any time more than 5 horses; therefore, our mechanical horsepower should be capable of operating the various implements which come within this range.

The control of the tractor necessitated considerable thought. When one considers the various positions which the operators of present-day implements have to assume, it is obvious that the connection between the operator and the tractor must be extremely flexible. For instance, the operator might be upon the top of a load of hay or on a harrow cart or on a binder seat, or any one of a dozen other places where the operator must ride on the implement to operate the various adjusting and control levers. Often, his position must be changed constantly; for instance, in pulling a load of hay with a hay loader. He is, to start with, on the rack and, after he has completed his loading, he is at least 7 or 8 ft. higher than his original position. The operator must be at all sorts of angles and distances from the tractor; it must be possible to shift quickly from one implement to the other, and the control must be positive in action at all times. We decided that the lines similar to those used with horses offered us the best solution to this problem.

The next problem was the construction of the control unit on the tractor itself, which would answer all the purposes required and, at the same time, be sensitive in operation. There were many ways of accomplishing this by using three or more lines but, realizing that the farmer was accustomed to only two lines, we limited ourselves to this number. Further, it was necessary to develop the control so that the lines would be used exactly the same as when driving horses. As a proof that we accomplished this very successfully, we often offered the control to men who had not previously seen the machine, asking them simply to start out as if they were handling horses. In all cases, they started and steered the tractor satisfactorily.

In the LaCross Model-M tractor we used a distinctive design of friction transmission. I wish to say, however, that, with the line control which we developed, it is not absolutely necessary to use a friction transmission. But we were thoroughly sold on the possibilities of this type, because it was easy to control with the lines. Due to the limited distance to which the lines could be pulled, it was necessary to arrange the friction drive in such a manner that the contact pressure was regulated proportionately to the power transmitted. We accomplished this by interconnecting our drawbar and control device so that, in starting a load for example, when a 100-per cent additional pressure is required on the friction drive, we obtain this additional pressure through the resistance at the drawbar. As soon as the load was under motion, the amount of power required to pull the load was reduced and the friction pressure was also reduced proportionately, this feature being automatic at all times. Adequate clearance of the tractor for cultivation of row crops is essential; in this machine, we had a minimum of 31 in. For short turning at the end of rows, we utilized a differential brake which was interconnected to the steering device. The angularity of the front wheels controlled the differential brake, applying it in such a manner as to give the required control for short turning. After constructing some 800 of these machines and placing them in various sections of the country, I can sincerely say that I believe a machine of this type will give the American farmer what he desires in the way of an economical power unit, which can be attached readily to all of the tools which he now uses.

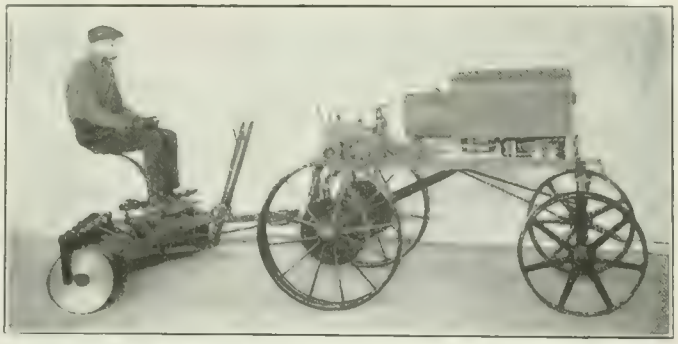


FIG. 25. THE CULTOR, A DEVELOPMENT OF THE MACHINE SHOWN IN FIGS. 23 AND 24 WITH LINE CONTROL DRAWING A DISC CULTIVATOR

Comment on Mr. Melcher's communication is perhaps superfluous although it may be pertinent to say that the American farmers have an investment of more than $3,500,000,000 in farm implements and machinery; therefore, there probably is something in Mr. Melcher's contention that the tractor should be made to utilize existing horse-drawn tools.

RECENT GENERAL-PURPOSE TYPES

At the 1922 Tractor Show in Minneapolis, Dent Parrett exhibited his little general-purpose tractor that he called the Cultor. Mr. Parrett's two-row cultivator has been mentioned previously, a limited number of them having been built in 1916. The two-row cultivator was discontinued and Mr. Parrett started to develop a light two-front-wheel-drive tractor, more or less along the lines followed in the Indiana and the Allis-Chalmers tractors. He figured that it might be possible to make this much lighter and cheaper than anyone had done before; therefore, he utilized a small two-cylinder air-cooled engine of about 9 or 10 hp. and built a machine that weighed ap-

FIG. 26—CULTIVATING YOUNG CORN WITH A GENERAL-PURPOSE TRACTOR

This Tractor Is Intended for Use with a Number of Specially Designed Tools That Are Capable of Direct Attachment and Has an Extension Steering-Device

proximately 1000 lb. This two-front-wheel-drive job was used experimentally for two full seasons in the field, as shown in Fig. 23.

Mr. Parrett states that their experience was that, so long as their own operators were with the machine, it did the work in a highly satisfactory manner. Its most serious limitation was that some care and discretion had to be used in getting the job hitched-up to the standard horse-drawn implement. In working out their hitches for this machine, it was the intention always to utilize the regular tongue of the horse-drawn implement when possible. To anyone who thoroughly understood how to make the hitches, it was a very easy matter to change over from one machine to another. The average time was 10 min. and it was often able to do it much more quickly. However, Mr. Parrett says that when they left this machine in the hands of the farmer, he almost invariably got into trouble with his hitches. After spending much time along this line, Mr. Parrett became convinced that specially built implements for the rear end

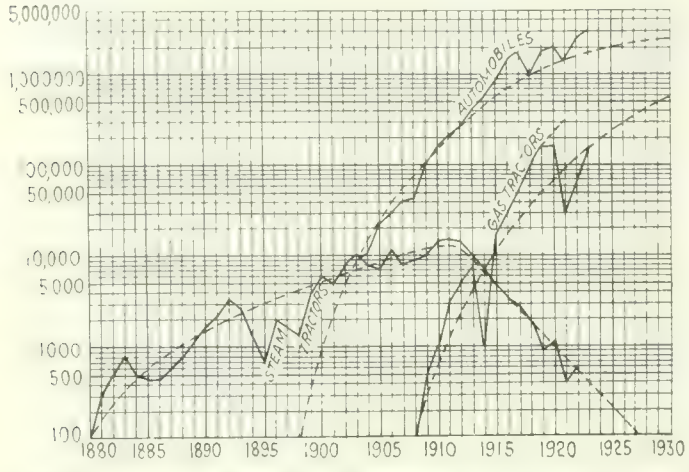


FIG. 27.—DIAGRAM SHOWING THE PRODUCTION OF AUTOMOBILES AND STEAM AND GAS TRACTORS

would be required to make the two-front-wheel-drive type successful so that there could be no possibility of going wrong when shifting from one implement to another. Mr. Parrett felt that this was not possible for the type of machine that he was trying to evolve, because one of the first things he set himself to do was to make a tractor that could be used with the existing farm implements. He finally conceived the notion of extending the framework forward, putting on two front wheels and hooking these up with the simplest kind of a line-drive for steering. These lines were arranged so that, when both of them were pulled back, the clutch would be released and latched out. A slight jerk on the lines and dropping them forward would engage the clutch; then, a right or left-hand pull would steer the front wheels in the usual manner. They did not attempt to complicate the line drive by including gearshifting. Mr. Parrett states that it is so seldom necessary to back-up in the field that the operator can get off and go to the tractor if he wants to shift into reverse. However, if desired, a third line can be attached to the gearshift lever and the control of the forward and the reverse speed be carried back to the implement, wagon or whatever is being operated, as shown in Fig. 24.

In its present form, the Cultor has been used two seasons in the field and, with the small two-cylinder air-cooled engine, has been found to be very satisfactory for any of the jobs ordinarily done around the farm with a team of horses. The machine weighs only 1200 lb. and will pull a mowing machine, a binder, a hay rake, a single-row cultivator, or, under favorable conditions, a sulky plow, that ordinarily would require three horses. A view of this machine is given in Fig. 25.

Another machine of the general-purpose type, having a high center clearance and a rear-wheel drive, has been on the market for the past 2 years; it is made by the Rock Island Plow Co. It is my understanding that this machine is the outcome of the company's experience with a double-row power-cultivator. The present job, however, is carried considerably beyond the single-row power-cultivator stage and, while not a great quantity of these have been sold, the experience to date is very encouraging and the Rock Island company believes it has a machine that will actually do everything that is to be done on the smaller farm up to 100 acres in extent.

Being an implement manufacturer, this company has worked out a number of directly attachable tools to be used in connection with this tractor, one of which is illustrated in Fig. 26. It has also developed an extension steering-device for use with a binder and similar tools. Having a friction drive, it can control clutching and declutching for both forward and reverse with a rope running over a pulley on the tractor frame and attached to the friction-drive lever. The initial engagement of the friction is accomplished by pulling one rope after which the pressure is maintained proportionate to the drawbar pull by the helical gears on the friction disc shaft. So far as I know, this machine is the latest development of the general-purpose idea to be placed on the market and its further progress will undoubtedly be watched with considerable interest.

For the past 5 or 6 years, the International Harvester Co. has done an enormous amount of work in its experimental department, looking toward the solution of the general-purpose-tractor idea. Some of the ideas along this line were presented to the Society two years ago, at the Tractor Show at Columbus, Ohio. No resume of the subject would be complete without taking the International Harvester Co.'s experimental work into consideration.

A final point to make in regard to the tractor industry concerns the speed with which the development has taken place. The development of our railway systems, the evolution of the grain binder, the perfection and utilization of the telegraph and the telephone and the enormous development of our various manufactures are all spoken of as the marvelous achievements of the past century. The motor car, the radio and, to a certain extent, the airplane are already considered the outstanding marvels of new development in the present century. I sincerely believe that, within the next decade, the development of the farm tractor and the motorization of American farming will prove to be a more spectacular development than any of the other things mentioned. We who have been working on the tractor problems are perhaps somewhat in the position of the man who could not see the forest because of the trees. It is perhaps a little difficult to stand to one side and get a proper perspective of what has already taken place in the industry. We realize more or less distinctly that the changes in ideas, the development of new types and the discarding of them have been, kaleidoscopic, to say the least, I wonder how many of us have realized how extremely rapidly these changes have taken place and how the idea of power farming has spread from one end of the Country to the other.

A chart[1] was published recently that shows the growth

[1] See *Automotive Industries*, Feb. 22, 1923, p. 360.

of the automobile industry since 1903. I have found considerable enlightenment in plotting on this chart such statistics as are available in regard to the growth of the tractor industry. From 1915 to 1919, the farm-tractor business in this Country was multiplied by 10; that is, from a production of about 15,000 to one of 150,000 per year. The time that corresponds more nearly to this in the development of the motor car was the period from 1905 to 1909. During this time, the production figures change from 20,000 to 100,000, *only one-half the rate of development shown by the tractor industry.* This chart showing the production of automobiles and steam and gas tractors is reproduced in Fig. 27.

Anyone can project the tractor curve for the next 10 to 20 years, but I am willing to go on record that, given a tractor with which it is possible to do all of the work that must be done on the farm, a production of over 1,000,000 tractors per year would result. Further, I believe it will be possible to reach this figure in less than 10 years if the tractor industry will take the information already available and evolve, within the next year or so, a type of machine with which this specification can be met. I believe the limitation lies with the tractor industry and particularly with tractor engineers, and not with the farmer, so far as adopting tractors for general work on the farm is concerned.

STEEL

(*Concluded from p.* 586)

(2) To modify the condition in which the carbon occurs
(3) To remove occluded gaseous impurities
(4) To combine chemically with the iron or the carbon, or both
(5) Either combined or free to form isomorphous solutions with the iron or to separate into distinct microscopic particles

The exact manner in which the added elements influence the iron-carbon system so as to produce new and useful properties in steel is not yet perfectly understood. Roberts-Austen and Spring found that one metal diffuses into another like salt into water. In general, solubility increases with the temperature. Metals and alloys will flow under pressure. Alloys may or may not react when brought into intimate association by fusion or pressure. Molecular mobility increases with the temperature. Upon the cooling of molten alloys, phenomena suggestive of freezing salt-solutions are observed. The depression of the freezing-point of a metal when another is added to it follows the laws of Coppet and Raoult for dilute solutions, and generally the phase rule of Gibb applies almost as well to the explanation of conditions of equilibrium in alloys as to similar problems in regard to liquid solutions.

We may almost say that the age of steel in the United States began with the development of the basic open-hearth process about 1888. Bessemer steel had been produced much earlier, while blast furnaces and foundries had been in existence in the Country from the early colonial days. We must still recognize that the making of steel is not an exact science. It is rather an art, to which scientific methods may be applied; in its fundamental operations it remains a handcraft industry, aided and guided by scientific control-methods. Young metallurgists are apt to become impatient because the steel-makers cannot manufacture their product 100-per cent perfect. This is the ideal for which conscientious manufacturers strive but which can never be perfectly attained.

If it is commendable to make two blades of grass grow where one grew before, how much more worthwhile is it to make 1 lb. of steel go where 2 went before, by improving the quality and the treatment and adopting a metal particularly suited to the requirements. Here we have real conservation in raw materials. The higher grades of ore are not believed to be inexhaustible and in making 1 lb. of steel we not only use one-half as much ore but also one-half as much fuel and refractory material as in making 2 lb. Furthermore, if the steel becomes a moving part of a machine, an automobile or an airplane, there will be a saving in motive power during the life of the machine. Sometimes such a thing does not lead so much to conservation as to an extension of use.

NEBRASKA TRACTOR-TEST ANALYSIS

(*Concluded from p.* 594)

Of the 17 that changed equipment, 3 also changed their rating. One of the three machines that withdrew was returned later for test. During this period 47 tractors have been eliminated from the Nebraska field because of their failure to complete tests or to appear for test after having made application.

Tractor builders have benefited in no small way from the reports of the Nebraska tractor tests which have furnished a mass of data never before available for analysis and study by designers. That a better product is one of the direct results of the testing program is indicated by the statistics in Table 1.

TABLE 1—STATISTICS OF NEBRASKA TRACTOR TESTS

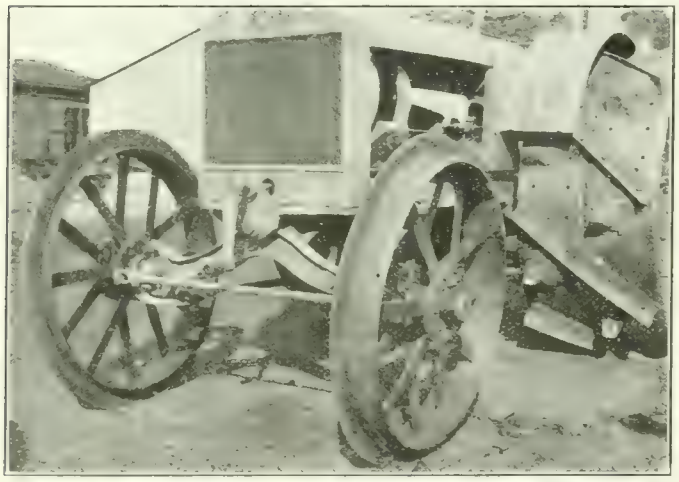
	1920	1921	1922
Percentage of Tractors Completing the Tests and Fulfilling All Original Claims	15.4	40.0	80.0
Percentage of Tractors Completing the Tests Which Could Not Develop the Power Claimed under the Original Specifications	41.5	26.7	20.0
Average Percentage of Increase of Fuel Economy of Kerosene Tractors, Using Four-Cylinder Vertical Engines, Tested in 1922 over Machines of the Same Class Tested in 1920		29.2	

SOCIETY MEETINGS

PROFITABLE CROPS FROM PEAT BOGS

Tractor Types for Reclaiming Waste Land Studied at Minneapolis Section Meeting

That 6,000,000 to 7,000,000 acres of peat land, at present sheer waste, can with proper treatment be made to yield better crops of many ordinary farm products than can be grown on other land, was the astonishing statement made by J. L. Larson at the May 2 meeting of the Minneapolis Section. Mr. Larson, who is a member of the faculty of the agricultural engineering division of the University of Minnesota, and G. R. B. Elliott, also of the University, have made a series of most interesting experiments in the types of tractor, plow and other farm equipment needed to reclaim waste land of the peat-bog variety.



Tractor Equipped for Marsh Plowing with Deep Skid-Rings on the Front Wheels and Wide Extensions with Widely Spaced Angle Lugs and Spade Teeth on the Driving Wheels

In the spring of 1922, a tract of land under the control of the Minnesota Agricultural Experiment Station was being put under cultivation for drainage experimental purposes. Information regarding the equipment necessary for peat-land farming is both meager and conflicting, especially with regard to the preliminary operation of breaking and preparing the first seedbed. The opportunity was therefore taken to obtain accurate information on the equipment required for the heavier operations and the best method of applying that equipment.

Description of Tract and the Equipment

The tract selected was several acres of "tamarack swamp" drained with tile the previous fall. Peat on the tract was from 5 to 7 ft. deep and had carried so heavy a growth of trees, principally tamaracks, birch, elm and maple, that it was estimated that 50 cords of stumps to the acre were removed in the clearing. The holes left by the removal of these stumps and the soft spots left by the back-filling of the drains were a very considerable factor in all the cultural operations, more particularly in the first plowing. It was considered that the job was a fairly difficult one, but thoroughly representative of the actual conditions that would have to be met by the farmer in breaking up timbered peat land. During the progress of the experiment, the water level was maintained about 3 ft. below the surface of the peat at the lower end and 4 ft. at the upper end. At the upper end of the tract the soil was fairly firm with considerable sod, while at the lower end the peat was very soft and much torn and pitted by the removal of the stumps.

In the first breaking of any land a very important consideration is the getting rid of trash and soft litter. On peat land it is also especially important to plow sufficiently deep to get under the deep underground root-stalks of marsh vegetation. The greater number of heavy root-stalks, with the exception of those of grass and small sedge, are to be found in the second 6 in. Ten inches to 1 ft. is, therefore, about a minimum depth for first plowing under average conditions on peat swamps other than grass marsh, and plows were chosen that would cut effectively to that depth, namely plows with 16 and 20-in. shares. These in their turn required comparatively heavy tractor equipment.

In all, five types of plow and three types of tractor were used. The most useful type of tractor for marsh plowing, as developed by the tests, is shown in the accompanying photograph, one of the many helpful illustrations Mr. Larson and Mr. Elliott showed as slides. The standing coulter proved most satisfactory for the work on timbered peat land. It is doubtful if the rolling coulter would have been successful in this type of ground, even had adjustments been possible.

An explanation should here be made of what the sod- or furrow-pusher actually is. It is not, as may at first be supposed, merely a mold-board extension. It is a curved steel piece attached inside of the mold board near the point of the plow and extending backward below and behind the mold board on a level with the bottom of the furrow. At the back it is cross-braced against an enlarged and strengthened landside. It was developed largely in cooperation with the Agricultural Engineering Department of the University of Wisconsin, purely as an aid in marsh plowing. Its purpose is to push the freshly-turned furrow still farther to the right, so that the next succeeding furrow will fall absolutely flat and then be pushed tight up against its fellow, completely covering the grass and the litter. The increase in the power required to operate the furrow-pusher was more than compensated for by the very much improved quality of the work done.

Special Wheel Equipment

Ample support to the tractor proved to be just as important as power. One tractor failed signally, not from any inherent defect in the design of the tractor or from lack of power, but because the special wheel equipment that would enable it to do its work was not available. It was like a strong swimmer thrown into the water and told to swim with stones tied to his head and his feet. The special wheel equipment on the successful tractor gave it 50 per cent more power in an emergency than the tractor that failed, although the successful tractor was of lower rating. The spade teeth served a very useful purpose in catching and holding submerged roots or timber in pulling out of a hole. The heavy skid rings gave the driver control of his machine on soft ground. This special equipment is not in any degree complicated or expensive. It can be easily made standard to be attached to the tractor by the operator for soft-ground conditions.

There are many tractors now owned throughout the country that cannot be profitably operated in the early spring or in wet weather. This is especially true in the working of peat land. Yet peat land can be cultivated, even at its wettest without injury to the seedbed. It can be plowed in the spring and seeded while the clay upland is still

too soft. This is an extremely important factor in financing farming operations as well as in general farm efficiency. It seems logical that the wider wheel equipment should be made standard for the wetter and softer districts and furnished upon the advice of the tractor dealer. It is also probable that in many cases where tractors are now unprofitable on soft lands, an expenditure of $100 would change an unprofitable into a profitable investment.

From the standpoint of mere efficiency in turning soil, the cutaway disc loaded to cut 7 in. was far ahead of any of the plows. In fact its power consumption per unit of cross-sectional area turned was less than one-half that of the plows. Its use is, therefore, strongly to be recommended under conditions where its use is practicable. It cannot be recommended for first breaking instead of using plows, for it required about five passages of the disc to give results equivalent to one plowing. The results of the work seem to indicate that disc machinery may be extremely efficient for all later cultivation.

The roller gave some remarkable results. Not only did it pack the peat and so form a better rootbed but, after the ground had been plowed, harrowed and rolled, even that part which was originally so soft and full of holes that it was difficult to get the tractors through it, became sufficiently firm to support horses for all later cultivation.

Several important things were brought out during the trials. What may be called the fundamental consideration upon which all the rest was built up was the better quality of work done by the heavier plows. This was later confirmed by the lessened weed growth on the deep plowing. During the summer, nettles were plentiful on the shallow plowing but not on the rest of the field. Although deep plowing on new peat will not help the crop yield the first year, there is no question that it gets rid of the old growth and puts the land in better condition forever after.

Power Required

Analysis of the power consumption developed several interesting facts. On the larger plows, the drawbar pull was constantly near or above 10 hp. with a reserve up to 17 hp. drawn upon at times. For the smaller plows, the power consumption was above 8 hp. with a reserve up to 15 hp. called upon. From this it would appear that for marsh breaking a tractor is necessary that is capable of developing not less than 12 working drawbar hp. with a reserve above that. This power and reserve is not necessary for later plowing.

In calculating the power consumed per unit of cross-sectional area, the 16-in. plows give almost the same results as the 20-in. plows of the same size. This is not what was expected, as it was thought that the vertical cut would offer a higher proportional resistance than the bottom cut. Apparently this was not the case, for the 20-in. plow gave no greater efficiency than the 16 in. of the same make.

The general proposition was established that for ordinary peat breaking the horsepower required can be figured readily and with fair accuracy on the basis of a 5-lb. pull per sq. in. of furrow-slice. If this is multiplied by the speed it is proposed to travel, the horsepower can be calculated in the ordinary way.

In answer to a question from A. F. Moyer, Mr. Larson said that the larger tractor-wheel diameter had been found better than the narrow or small wheel in work on peat land.

The question of what crops are best suited to peat land brought out some striking facts. Mr. Elliott, whose work deals particularly with crops, reported that about two-thirds or three-fourths of the ordinary farm products will do better on peat land than on other land. The other one-fourth of the list will do better on other land than on peat. Corn, potatoes and rice are good. Wheat will not do anything; but oats will grow about twice as much. Hay grows well and so do all sorts of grass. Onions thrive and will range from 500 to 600 bu. on 6-in. level land per acre. Carrots yield over 600 bu. an acre, sugar beets 20 tons to the acre.

Asked by Mr. Sikes at what speed per hour most effective and efficient work had been done, Mr. Larson answered that 2¾ m.p.h. had been found the best plowing speed, disregarding the number of acres covered per day. The possibility of miring is doubled by running at slow speed, but a very high speed is also undesirable. The bog is like rubber or tar. The faster one moves over it, the less impression is made.

The discussion closed with Mr. Moyer's request that Mr. Larson prepare a curve of plowing efficiency showing the cubic feet of furrow turned per drawbar-horsepower per hour, as a true measure of plowing efficiency, very nearly in proportion to the plowing cost when the depth is considered and human labor per horsepower is fixed.

In addition to Mr. Larson's paper, this last meeting of the season included a showing of the popular film, Electricity in the Motor Vehicle, sent out by the North East Electric Co., and Mr. Scarratt reviewed in detail the National Tractor Meeting at Chicago.

The officers elected for 1923-1924 are all men experienced in Section work and devoted to making the Minneapolis Section a success. Chairman, Victor Gauvreau; Vice-Chairman, A. F. Moyer; Secretary, Phil N. Overman; Treasurer, J. S. Clapper. A. W. Scarratt will represent Minneapolis on the National Nominating Committee at Spring Lake.

FOUR-WHEEL BRAKES DISCUSSED

Engineer Describes Hydraulic System Before the Detroit Section

A system of four-wheel brakes actuated by hydraulic pressure was described at the meeting of the Detroit Section on May 17. The speaker, Malcolm Loughead, described the important mechanical features of his particular design, answered numerous questions and discussed some of the disadvantages cited against four-wheel brakes in general. The meeting attracted over 200 members and reflected the great interest that is being taken in four-wheel brake development.

Malcolm Loughead

The hydraulic pressure in the Loughead system is built up in a cylinder that is mounted near the fulcrum of the brake-pedal. A piston in this cylinder is directly connected to the lower end of the brake-pedal forging and is forced into the cylinder by the depression of the brake-pedal itself. The ratio of the movement of the pedal and the piston is about 4 to 1. Four metal pressure-lines or tubes lead from this master cylinder to points on the chassis frame adjacent to each of the four wheels. Flexible tubes lead from these points on the frame to individual brake-actuating cylinders mounted on each of the four brake-supports. These flexible tubes are made of heavily reinforced rubber tubing or hose with flexible metallic tubing running through its center.

Each of the brake-actuating cylinders contains a pair of opposed pistons, one at either end of the cylinder. These pistons are forced apart by the hydraulic pressure set up in the system when the pedal is depressed and it stands to reason that the pressure on both pistons in all four actuating cylinders must be equal. The brake-bands are of the external contracting type and are pulled together by two short independent levers. One end of each of these levers bears on the head of one of the pistons in the actuating cylinder and the other end exerts a pull on the brake-band end, tangential to the drum, when the brake-pedal is depressed.

Any leakage of liquid from the system is compensated for by mounting a small reservoir on the dash that automatically replenishes the master cylinder. When the master-

cylinder piston is in the off position it uncovers several small port holes that are in direct communication with the reservoir.

Advantages Claimed for Hydraulic Brakes

The speaker made several definite claims of superiority for the hydraulic type of brake over the mechanical type. Since there are fewer mechanical joints in the hydraulic system, the friction loss in the operating mechanism is claimed to be lowered considerably. This advantage becomes pronounced after several months of service, when, due to a lack of proper lubrication, the mechanical brakes show wear in some joints and seizing or binding in others. The flexible connection between the brakes and the chassis prevents trouble due to the improperly related movement of a mechanical brake-linkage. Brake adjustment is not affected by a change of loading in the car. The movement of the body in relation to the axles when traveling over rough roads does not react against the brake-pedal. This condition does exist in some forms of mechanical brake and is particularly noticeable when coasting down a rough grade, the brakes having a tendency to lock and release alternately, due to the spring movement. Pedal pressure in the hydraulic system is moderate. It is not necessary to employ any servo mechanism because of the higher mechanical efficiency, the absence of any lost motion and the large contact surface of the external brake-band.

Mr. Loughead described an accurate method of measuring the distance required to bring a car to a stop. A pistol is mounted rigidly on the car frame and its trigger is connected to the brake-pedal so that the depressing of the pedal 1 in. fires a shot into the road surface. When the car comes to a stop, the distance is measured from the muzzle of the pistol to the point where the shot entered the road. This gives a far more accurate result than depending upon the driver to depress the pedal when he crosses a line or is given a signal. Test results using this method were presented by the speaker for a car weighing 4400 lb. with driver; weight on the front wheels, 2000 lb.; weight on the rear wheels, 2400 lb.; using 35 x 5-in. tires inflated to 65 lb. per sq. in.; and operating on a concrete road.

Braking on	Distance Required To Stop, Ft.
Rear Wheels Only	89.2
Front Wheels Only	67.6
All Wheels	36.8

Mr. Loughead recommended providing approximately 1 sq. in. of brake-lining for each 12.5 lb. of total car weight, fully loaded. Increasing this ratio to 16 lb. results in burned linings and a reduced coefficient of friction.

External Brakes Preferred to Internal

External brakes are preferred by Mr. Loughead for several reasons. When internal brakes are used repeatedly or on long grades, the expansion of the heated drum may reach a point where contact with the lining is not possible. With external brakes, heating the drums results in an increase of available pedal travel. Oil and grease are less likely to leak from the axles onto the external brakes. Due to the fact that both distortion and expansion must be combatted in the internal design, it is difficult to attain a high ratio of pedal movement to brake-shoe movement for a given pedal-pressure.

The liquid used in the hydraulic braking system is a mixture of alcohol and glycerine; 60 per cent of glycerine and 40 per cent of alcohol. The speaker favored having all four brakes adjusted to apply at the same instant instead of having the rear brakes act in advance of the front. If one of the lead lines or hoses leaks or breaks, the system becomes inoperative. About 35 lb. would be added to the weight of a front axle of the Cadillac car by adopting front-wheel brakes of the hydraulic type. The front-axle forging of any car must be redesigned to withstand the braking torque when front-wheel brakes are added. It is claimed that the tire mileage is increased with four-wheel brakes because of a lesser tendency to lock the wheels in ordinary service and a reduction in skidding. Rawhide is used to pack the pistons and prevent any leakage of the fluid from the hydraulic actuating cylinders. The brakes do not need to be relined frequently when used on all wheels since the wear is distributed over a much greater braking surface.

T. J. Litle, Jr., outlined his experience with four-wheel brakes of the hydraulic type, stating that he had found them very effective and had not experienced any serious difficulty due to locking, or because all wheels did not brake uniformly. Clarence Carson took issue with Mr. Loughead regarding the attainment of satisfactory equalization. He said that the wide variation in frictional coefficient of commercial brake-lining upsets the finest adjustment or mechanical equalization by producing a totally different braking effect on each of the four drums, even though the band pressure might be equal. A. L. Clayden discussed the scheme of braking on diagonal wheels, saying that this was done originally in England by the Argyll engineers to insure at least one front and one rear wheel running free in case the other pair locked. It was assumed that having two diagonal wheels free would provide better control of the car in a skid or for steering. This plan is now in disfavor because the increased stopping power with all four brakes acting together is of more practical value for safety reasons than the theoretical advantage of diagonal braking.

HIGHWAYS AND TRAFFIC IN A CITY

Major F. S. Besson Gives Washington Section Results of His Observations

Several newspapers ran front-page accounts of the Washington Section's meeting on May 4 when Major F. S. Besson, acting engineering commissioner of the District of Columbia, spoke on Highways and Traffic, basing his conclusions on observation of the transportation situation in the City of Washington and other municipalities in which he has been studying traffic conditions.

In introducting the speaker, Chairman Warrington reminded the audience of the increasing importance of transportation in an age when we figure not how far one place is from another, but how long it will take to cover that distance. The 40 miles from the City of Washington to Baltimore is now thought of not as 40 miles but as a 45-min. run. Increasing improvement in transportation is responsible for the change in viewpoint, as it decreases the time necessary for getting from one place to another.

Major Besson explained that streets may be divided into three classes: rapid-transit streets, local streets, traffic highways. Rapid-transit streets, if properly laid out, invariably become business streets. The motorist should use them only to transact business. Local streets are residential, commercial or industrial in character and should be used, so far as possible, only for the purpose for which they were designed. Traffic highways exist primarily for hauling and motoring. They should afford convenient connections between residential, commercial and industrial districts, and between the city and the surrounding country. When a traffic highway becomes overburdened, the overflow takes to rapid-transit and local streets. Business people then complain that the congestion on the roadways interferes with the transaction of business. Often the traffic engineer looks no farther than these rapid-transit and local streets for the trouble, whereas it originates in the lack of sufficient traffic highways, and the remedy is to supply more of them.

Traffic Problems in City Planning

From a traffic standpoint, an intersection consisting of more than two streets is objectionable, though from the standpoint of appearance very beautiful effects can be obtained. Where there is sufficient area for the installation of a central circular park, and rotary traffic to the right can be established, conditions are greatly improved. If there is any latitude in making a choice, a car-line street should not pass through a common intersection with two other streets. Where such an intersection of a car line and two other streets is unavoidable, the installation of platforms or

"islands" will be a great protection to pedestrians.

These principles should be remembered in laying out city blocks. For some streets it is desirable to discourage traffic, except that having to do with abutting property. The roadways of these streets should be wide enough for local requirements only and need not be continuous for long distances. For others, through traffic is a prime consideration, and interruptions to safe and rapid travel should be few.

Streets have both horizontal and vertical directions. Only the former have been discussed so far. Vertical directions are usually treated under the heading of grades. No definite rules can be given for the maximum permissible grades. Judgment alone can gain the best results in fitting streets to the terrain. A few cities have examples of street grades of close to 20 per cent. Some rapid-transit streets are known to have grades of more than 10 per cent on which, of course, operation is costly. A street cannot serve satisfactorily as a traffic highway if it has grades as steep as 10 per cent. Even 6 to 8-per cent grades are undesirable, but they may be used for short lengths, if lesser grades are impracticable. If they continue for more than one block, 6 to 8-per cent grades will slow up traffic markedly. Grades of from 4 to 6 per cent are proportionately less undesirable, while any grades up to 4 per cent may be used without hesitancy for traffic highways.

Choice of the Right Grade Imperative

The grades to be adopted depend to a great extent on the nature of the terrain. In this matter foresight is needed, for much money has been spent in correcting at a later date the "follow-the-ground" policies of an earlier design. In the establishment of grades on rapid-transit streets and traffic highways, the needs of traffic are of first importance. On local streets, the needs of abutting property are given greater consideration, though intersecting traffic highways or rapid-transit streets may definitely fix for short distances the grades on local streets.

Whether or not it will be feasible to develop an area often depends upon the grades established for the surrounding streets. While the basis of a highway system of a city should be a rectangular plan, such departures from the plan should be made as will facilitate traffic, aid real estate development and simplify drainage. Real estate operators should be encouraged to develop property along natural lines to the fullest extent of their financial and artistic abilities, as long as traffic and drainage requirements are considered; but in all developments there is an economic limit beyond which it is not advisable to go. In developing ground for the sale of moderate-priced homes, house and lot to sell for certainly less than $30,000, it is generally necessary for the land operator to destroy practically all the native trees. Unless parks are bought and paid for by the municipality, they are such a large burden upon the remainder of the land that none but the very wealthy can afford to buy it. Of course, in out-of-the-way sections of the suburbs of a city, where land will probably never sell for more than 20 cents per sq. ft., it is practicable to set aside a half-acre of rough ground for each dwelling and to keep the trees in their native state. On the other hand, such an arrangement cannot be countenanced where it would interfere with the proper economic growth of the city.

Width a Fundamental Consideration

We must look into the future when we lay out our highways. The width of streets is one of the fundamentals vitally affecting the expansion of cities and, while it is a mistake to make streets too narrow, it is also a mistake to make them too wide. As a large portion of the area of a city is occupied by streets, above 30 per cent of the total area on the average, if they are unnecessarily wide, land otherwise available for buildings is wasted. Space other than that used for vehicles or pedestrians is extra or reserve width. It is provided as a matter of civic pride or to add beauty and comfort, and also to permit the expansion of the roadway and the sidewalks for future traffic.

Widths may vary according to the class of street. Experience shows that in laying out a rapid-transit street, provision should be made for double tracks and, when the business character of the street has developed, there should be available a roadway of at least 54 ft. A total of 54 ft. is the minimum width permitting free passage between street cars and vehicles parked at the curb. This width allows the installation of car-loading platforms, so that vehicles can pass between them and the curbs while the cars are taking on and discharging passengers. The provision of these platforms is important, for they protect persons boarding and leaving the cars and give vehicles a freedom of movement that adds greatly to the traffic capacity of the street. Further widening within a certain range, as for instance to 65 ft., is uneconomical. It is too narrow for three lines of traffic between the track and the curb and serves two lines not much better than a width nearer to the minimum.

For streets of greater importance, a step up to approximately 72 ft. is necessary. This roadway is wide enough to accommodate two streams of traffic between vehicles at the curb and the street cars. Actually, however, such use is curtailed by the tendency of traffic to take the center of the available space in single file. An excellent plan for using a 72-ft. car-line roadway is to stop cars at an angle or perpendicular to the curb. This not only gives shoppers increased parking facilities, but also allows trucks to unload to advantage. At car-loading platforms, vehicles may stop parallel to the curb and still leave a free passageway.

A roadway cannot serve satisfactorily as a traffic highway unless it can provide for two unhampered lines of moving vehicles in either direction. In the development of such a highway, Major Besson believes that an expensive pavement for the full width is not justified in the earlier stages. Using a cheaply constructed pavement for the entire width gives a surface with a probable life of from 10 or 15 years, but with a high yearly maintenance that rapidly increases as the payment grows older and traffic increases. The money spent for such a pavement is spread over a large area, but when a better style is demanded, the old pavement has little or no salvage value. The more economical way seems to be a progressive development from a 9-ft. to an 18-ft. roadway and on through to the final width of 54 ft. One advantage of this gradual development is that construction is paid for in installments commensurate with the volume of traffic that is served.

The problem of pavement design to take adequate care of transportation gross weight is today well in hand. To provide economically for the probable volume of transportation is a larger and more difficult problem. A strong pavement can readily be substituted for a weak one, but unless plans have been exceptionally well made, it is seldom that a wide roadway can be substituted for a narrow one in the heart of the city. Everything possible should be done to realize the full capacity of the roadway width that is available.

Effect of Width, Length and Weight of Vehicles

The use that can be obtained from a given width of roadway depends upon the width of vehicles and this, except in the case of street cars, should be limited to not more than 7½ ft. Permits may be granted for wider vehicles, subject to restrictions as to the routes to be followed and the time of day passage is to be made. The length of vehicles in the near future will also need restriction, especially if the use of six-wheel trucks and trailers develops. An overlong truck is difficult to park without closing traffic lanes, and in turning a corner, the overlong truck is liable to swing out and damage other vehicles.

Not only the width and the length but also the weight of the vehicles must be considered in developing the maximum capacity of highways. It would not be wise to eliminate the 7½-ton truck, for its load would have to be carried by more than one truck. More space would be taken on the highway, increasing congestion and wear, for if two types of truck are equally well-designed, carrying the load on four wheels will do less damage than carrying it on 20. Gross weight alone is not the all-important factor. Speed,

unsprung weight, wheel-loads, character of tires, tractive stress on the pavement, all these enter into the question.

Maximum Traffic Capacity Means Control

Passing on to the control of heavy traffic, Major Besson took up Fifth Avenue, New York City, before and after the installation of the new traffic towers, as an example of what efficient control can do. The present system of treating vehicular traffic between 23rd and 59th Streets as a unit, together with the control of pedestrians, has doubled the capacity of the avenue during rush hours. Today approximately 15,000 vehicles pass in 10 hr.

Major Besson believes that one-way traffic is fundamentally wrong, although under certain conditions it serves a good purpose. If, for instance, two roadways carrying mostly through traffic lead directly between two points, one of them may well be used for travel in one direction and the other for travel in the opposite direction. Ordinarily, however, the system of one-way streets only adds to the congestion of both one-way and two-way streets, the latter generally rapid-transit streets with two-way car tracks.

Suggested Tax on Weight

Within the permissible gross weights for vehicles, certain regulation is, however, required. A basic rule should be that trucks may not carry more than the weights for which they were constructed, and in accordance with which the owners have paid fees in obtaining operating permits. The motor-vehicle industry condemns overloading and builders generally are arriving at a point where they furnish caution plates stamped with the chassis and body weights and the load capacities. In accordance with the data furnished by the builders, the license bureau should make certain that the permissible gross weights are painted on the sides of all cargo vehicles, and fees should conform to these gross weights. The main principle of the suggested rate is that vehicles are taxed on a graduated scale. It may not be absolutely accurate as judged from the pavement standpoint, but it is as nearly so as can be made under the present state of our knowledge. Such a tax, if properly administered, would return more than $2,000,000 a year, at the rate of approximately $10 for a Ford roadster, $16 for an ordinary touring car and $140 for a 7½-ton truck, the maximum limit. The gasoline tax, on the other hand, would be inadequate, unless an excessive tax per gallon were levied.

Major Besson's paper, which was well-illustrated by many slides, was followed by discussion of some of the points raised.

During the business session that preceded the presentation of the paper, A. W. S. Herrington, vice-chairman of the Washington Section for the coming year, was elected to represent the Section on the National Nominating Committee that will meet at Spring Lake during the Summer Meeting of the Society. W. S. James, of the Bureau of Standards, has been reappointed chairman of the Meetings Committee, and P. B. Lum, of the Auto Car Sales & Service Co., is to be chairman of the Membership Committee.

AERODYNAMICS OF MILITARY PLANES

Fundamental Principles of Design Presented to Dayton Section by W. F. Gerhardt

Two hundred members and guests of the Dayton Section were at the Engineers Club on May 1 to hear W. F. Gerhardt speak on Fundamental Principles of the Design of Military Airplanes. Mr. Gerhardt, an aeronautical engineer in the flight test section of the Air Service at McCook Field, covered very thoroughly the problem of aeronautic-engineering technique in the development of military aircraft. Mr. Gerhardt introduced his subject by analyzing a typical modern research problem to determine the logical sequence in which military-aircraft development should be studied, for in this, as in other fields, it is of little use to begin to do a thing before what is to be done is known.

The paper proper began with a discussion of the mark toward which the development of military aircraft is aimed. It went on to analyze the means at the disposal of the aeronautic engineer in the solution of tactical problems, so that designs for military airplanes can be drawn in accordance with the practical demands to be made upon them. After pointing out the general inter-relation of these technical means of solution, Mr. Gerhardt discussed the relative importance of different types of airplane, propeller, engine, armament and other equipment. Passing on to aerodynamics, he demonstrated that the general theory of airplane performance is based upon an analysis of the forces acting on an airplane, and that by this analysis, such quantities as speed, rate of climb, radius and velocity of turn, can be expressed as functions of the airplane's dimensions. The graphic solutions that Mr. Gerhardt has worked out permit the selection of dimensions to secure any performance desired. The designing theorems showing what dimensions of the airplane most affect any given performance were also stated. With these the designer can be sure to make his improvement in the right direction for economical operation. Similar graphs and theorems were shown for the stability and the controllability of the airplane.

Mr. Gerhardt's very valuable paper closed the Section year, as there will be no meetings of the Dayton Section in June, July and August.

ALLOY-STEEL AND BEARING ALLOYS

Crucible Process the Best for Former—Characteristics of Latter Described

At the regular monthly meeting of the Metropolitan Section on May 17 two carefully prepared papers were presented. The first by J. A. Mathews, president of the Crucible Steel Co. of America, dealt with the Present and the Future of Alloy-Steels, and the second by C. L. Landon, chief engineer of the American Bronze Corporation, Berwyn, Pa., was on Copper-Rich Bearing Alloys.

Doctor Mathews said that it is seldom that any process is discovered that cannot be improved upon, but that the crucible process of making steel is an exception and had never been surpassed. The Bessemer process, invented in 1865, is a marvel for quantity but not for quality. The Siemens-Martin or open-hearth process, invented in 1868, is also a quantity process but is superior to the Bessmer in the quality of the steel produced. The fourth and latest process, the electric furnace that very opportunely came into use during the closing years of the nineteenth century just prior to the introduction of the automobile, offers the nearest approach to crucible steel, but seldom equals and never excels it. Crucible melting is not suitable for manufacturing large quantities of low-carbon steels but the electric furnace is ideally suited for this work. Crucible steel will continue to be used for the highest grades of tool steel and the electric furnace for the highest types of alloy-steel. The chief difficulty with the electric furnace is that the furnaces are built faster than skilled operators can be trained; it is not a cure-all for steel troubles, nor an automatic device that can be operated by anyone, regardless of his experience or lack of it. The problem of steel melting consists of melting in the absence of oxidizing conditions and out of contact with the products of combustion. The crucible, practically sealed, gives the nearest approach to ideal conditions; the electric furnace has little to contend with in the way of contact with the products of combustion and little air circulates in the furnace. But the unit is larger and the ingot is larger, which is its first disadvantage, and pipes, seams segregations, blow-holes and surface imperfections increase in geometrical proportion to the size of the ingot. The 4-in. crucible ingot is the ideal size and when the steel is skillfully melted and poured blow-holes and segregations are negligible. The best melted steel should pipe but the pipe should be located near the top and enough metal should then be discarded to get below it.

Present Practice Criticized

Present practice both of making and of using alloy-steels is not altogether sound. Analysis is over-emphasized. Steels of identical analysis may differ widely. Tension tests do not always show the difference. Steels apparently identical differ in brittleness. Comparative analyses must be used with judgment and with much additional information taken into consideration. Many users seem to think they are getting more for their money from the maker who offers a greater percentage of alloy. Steel-making ability rather than chemical analysis should be the determining factor, and the maker should be chosen who makes the best steel of the specified percentage of alloy.

In most cases, sulphur and phosphorus should be as low as possible, but for an equal carbon-content they are less injurious in crucible steel than in other grades. In electric steel low sulphur may be taken as an indication of the success with which deoxidizing conditions have been attained in the working of the heat. Sulphur in steel exists as separate microscopic particles of manganese sulphide and is liable to segregate. Other inclusions, non-metallic and non-ferrous, that may be present in smaller or greater amounts, are not shown by analysis and frequently escape detection under the microscope. Oxides of the very elements used to make the alloy may be present and analysis may show the total amount of alloy present without showing that part of it is an oxide or a silicate. Slag may be finely divided. The effect of inclusions is essentially that of minute internal cracks. An examination of material that has cracked often will reveal that the crack runs through groups of inclusions or has its origin in a segregated area.

During the war very serious trouble developed in material used for aircraft production, due largely to two defects that were christened "snowflakes" and "hairlines." The snowflakes were caused mainly by poor melting and pouring by inexperienced makers. One company was reported to have melted 1000 tons of steel to deliver 100 tons of billets of a certain analysis. In one case it was shown that the snowflakes could be made to disappear by reworking the steel at proper heats. Hairlines are less readily detected because they are usually so minute that they do not appear until the part is finished and polished. They seem to be definitely associated with minute inclusions, drawn out into filaments, from which the included matter falls out during the grinding and polishing. Although their true significance as a cause of failure has not been positively determined, if they were too numerous, appeared stringy or occurred in fillets, crankshafts showing them were rejected. The name "sonims" has been suggested for non-metallic impurities in steel.

Experiments that have been made with chrome-nickel steels that were first class in every particular showed them to be not as sensitive as supposed, and that the material had not been seriously injured by the excessive temperature of drop-forging. Other unusual tests failed to develop any defects. It would be desirable if forms of non-destructive tests could be developed that would tell the true condition of things in the finished part without destroying it or involving the assumption that the material in the part is the same as that of other sample parts that had been tested. Magnetic analysis has been attempted but with small promise of success except in particular instances. Conductivity tests cannot yet be interpreted in terms of other properties.

An investigation of the fatigue of both nickel and chrome-nickel steels has shown that, although heat-treatment raises the proportional elastic-limit and the tensile-strength, it adds little, if anything, to the fatigue resistance. Fatigue failure has been proved to be a progressive failure, starting in all cases in some defect or irregularity of the internal structure or external surface. Freedom from flaws is therefore more important in members that are to be subjected to repeated stresses than in those having few repetitions of load.

The Human Element in Steel Making

The manufacture of fine steel depends on the human element engaged in the making of it and on the exercising of never-ceasing care. This is also true of the heat-treatment of the finished parts. The consideration of a simple alloy-steel in all its properties would call for the following program: (*a*) complete chemical analysis, including elements not usually determined and the included gases; (*b*) the determination of the recalescence and the decalescence temperatures as a basis for subsequent heat-treatment operations; (*c*) a wide series of hardening experiments at a variety of drawing temperatures; (*d*) tensile, impact, vibratory and dynamic tests under all conditions of heat-treatment; (*e*) microscopic tests for investigating the grain size and for determining the constituents present and corresponding to a definite heat-treatment, slag and other inclusions, segregation, ferrite streaks, and the like; (*f*) tests of the magnetic and the electrical properties corresponding to changes in the physical and the chemical condition of the steel; and (*g*) hardness tests by the Brinell and scleroscope methods.

There is little doubt that the electric furnace will be the source of the alloy-steels of the future when the highest quality is demanded. Its principal advantages lie in the facts that easily oxidizing metals like vanadium, chromium and manganese are readily handled and that smaller amounts of them need be handled to give a final minimum of content in the steel; that less of the oxides will be produced and removed from the steel; that sulphur and phosphorus can readily be controlled and eliminated; that as the steel is made in the furnace itself rather than in the ladle, a better opportunity is afforded for the solution, the diffusion and the homogeneity of the product; and that it performs an economic function because of its adaptability for handling and recovering the alloy values contained in scrap.

H. M. Crane said that his experience bore out Doctor Mathews' statement that the steel's being clean and free from non-metallic impurities is in some ways more important than the alloys it contains.

Effect of Tin and Copper Proportions on Bearing Metals

Mr. Landon gave many interesting facts regarding the structure and characteristics of bearing metals, of which, he said, the tin bronzes are the most important. Although they always contain other elements that may have been added intentionally or may be present as impurities, the structure and characteristics of a given alloy may be predicted by the relative proportions of these two ingredients. In solidifying they take a series of crystal forms, each stable under definite conditions of concentration and temperature. At high temperature the mixture is entirely fluid. As the temperature is lowered progressive solidification takes place with a characteristic dendritic or tree-like structure, the arms being composed of tin-rich Alpha crystals in which are imbedded Delta crystals, still richer in tin. This phenomenon of fractional solidification is known as "liquation." If allowed to proceed to an extreme, liquation is very pronounced, large areas of high tin-content forming and producing a condition called "tin sweating." Molten copper and tin oxidize readily. The addition of zinc reduces the copper oxide, forming zinc oxide. Both zinc oxide and tin oxide are more injurious than copper oxide, but they both rise to the surface and may be removed. Phosphorus is a still more powerful deoxidizing agent. The metals in which it is used are called phosphor-bronzes, although the phosphorus-content may be very low or even zero. The brittleness increases with the tin-content, the normal requirements of a "hard cast bronze" being satisfied by a tin-content of from 10 to 14 per cent. If an intensely hard cast bronze is desired, approximately 3.6 parts of zinc may be added to a 14-per cent tin-content. This produces what is known as the Navy H alloy. The addition of smaller amounts to a 10-per cent tin concentration-mixture forms the Navy G and S.A.E. No. 62 alloys. The addition of lead decreases the original homogeneity, the strength and the toughness and provides a new series of metals of specialized characteristics that possess good machining qualities and an ability to "wear in" and "seat" themselves. These characteristics increase with an increase of the lead-content and are not obtained in the harder alloys.

In addition to the copper-tin alloys, copper-zinc alloys, or "brasses," are used as bearing metals, usually in a worked form. Their strength and ductility increase with an increase of the zinc-content up to the limit of the Alpha field. Lead is frequently added to facilitate machining. Alloys with a zinc-content of from 35 to 40 per cent have had a rather extensive use as bearing metals, especially in the smaller sizes. In large sizes a 10-per cent content is frequently used. When it is prepared for cold-working a slight amount of tin is added.

The only condition that must be met in a bearing is the constraining and defining of the motion of one part of a mechanism relative to another part of the same mechanism. Any bearing that performs this function satisfactorily and maintains this condition of mechanical satisfaction for a sufficient length of time consistent wth current practice is satisfactory mechanically, regardless of its type, material or other considerations. If cost and operating requirements also are satisfactory, every engineering condition is fulfilled. As wear is inevitable, the only factors that can be controlled are the total rate of wear and the relative wear between the journal and the shaft. The ability to resist wear depends upon the internal structure of the metal, that is, its molecular cohesion, which in turn depends on the shear strength, the tensile-strength and the density of the material. The relative surface hardness of the journal and bearing should be such as to localize the greater part of the wear on the part that is easiest and cheapest to replace.

Requirements of a Good Bearing-Metal

In the discussion that followed Sam Tour referred to the fact that single pure homogeneous metals, irrespective of strength, do not make good bearing-metals, but that these are composed of intimate mixtures of hard and relatively soft particles of microscopic size. The hard particles support the load and resist the wear when actual contact exists between the bearing surfaces; the soft particles allow the hard particles to adjust themselves to the journal. The soft particles wear down slightly below the surface of the bearing and form slight depressions in which some of the lubricant is held when the surfaces are brought into contact with each other. It is this characteristic of certain alloys to form these slight depressions and provide a means for retaining the lubricant that characterizes them as true bearing-metals. It is not strength, toughness or ductility that does it, but the difference between its component crystals. If a journal were absolutely smooth, true and cylindrical, so that polishing would not be necessary, the journal could be made infinitely hard and would give perfect performance on a lubricant-retaining bearing-metal. But as perfect alignment is not possible the journal must be soft enough so that the bearing will polish it and the hard particles in the bearing must be soft enough so that they will not continue to scratch and wear the journal. The hardest particles should be of the same hardness as those of the journal and there should be a polishing effect rather than an abrasion tendency between the two metals.

Heat conductivity is another important factor. The amount of attention that the bearing will receive must also be considered. If forced lubrication is used bronze bearings would be satisfactory, but if the human element enters a babbitt-lined bearing would be preferable. A bronze bushing is now being made by compressing granulated metals. The powdered oxides of tin, lead and copper, together with graphite in any desired proportions, are compressed into the form of a bushing and are then reduced in an atmosphere of hydrogen. This results in a very porous bearing that when boiled in oil, absorbs from 5 to 6 per cent of its weight of oil and acts as a self-oiling bearing. Another laboratory has taken powdered metals instead of their oxides and compressed them with or without graphite, heating them to a temperature at which they just begin to amalgamate and then boiling them in oil.

H. M. Crane, referring to the use of lead in bearings, described a transmission brake with a hardened brake-drum and shoes of what was called plastic bronze, having a large lead-content. When the brake-drum was not run to a point of extreme heat, even without lubrication a mirror-like polish was obtained on the drum without any wear on the brake-shoes. A single set of liners could be used for 2 years with possibly 1/32 in. of wear. On airplane engines babbitt metal formerly was used, but recently a bronze with a high lead-content has been tried, which apparently can stand occasional metal contact, and because of its greater rigidity and because it is homogeneous, will run indefinitely without disintegration.

The meeting was concluded by a series of motion pictures illustrating the historical development and the modern processes of alloy-steel manufacture.

RACES ENCOURAGE DESIGN PROGRESS

Fred Duesenberg Credits Track with Many Important Engineering Developments

Fred S. Duesenberg

Lessons taught on the speedway and race track can be applied with modification to touring-car practice to very great advantage. This has been the experience of Fred Duesenberg who has made such an excellent record in the design of winning racing cars and engines. He addressed the Indiana Section of the Society on May 3 on Engineering Information from the Race Track.

The struggle for extreme endurance, extraordinarily light weight, great strength and maximum efficiency for a given size of engine, exacts a high degree of engineering proficiency. Proper lubrication stands foremost as a feature of racing design that must always be kept in mind. Mr. Duesenberg listed the outstanding points of design and construction of racing cars in the following order of importance:

(1) Cylinder-head with properly located valves and spark-plug; combustion-chamber form
(2) Pistons; weight, balance and general form
(3) Intake manifolding; design and length are of major importance; size and inner surface contour next
(4) Valve operating mechanism; design of first importance; weight of operating parts next
(5) Valves; size and port area of great importance; lift, second; timing, third
(6) Connecting-rod; balance, weight and design
(7) Bearings; size, lubrication and material of importance in order named
(8) Crankshaft; balance, design and material
(9) Cooling of engine and oil
(10) Exhaust manifold and piping
(11) Rear axle; weight first and design second
(12) Front axle; design first and weight second

All of the details mentioned in this list should receive careful consideration in touring-car design, but the order of importance is materially changed. For example, proper manifolding and carburetion would stand near the top of the list.

Racing cars must be steered easily, they must be properly balanced, the weight must be minimized and much attention must be given to the form of the body to reduce head resistance from the air. Reduction of weight must be made with the greatest care, for this has been a pitfall for many designers. They often drill holes in important parts, taking off from 5 to 10 per cent of the total weight at a sacrifice of from 40 to 50 per cent in the strength. The engine, the gas tank and the radiator must be mounted so that twisting of the chassis will not loosen them. Accessibility is of major importance in racing-car design and in this respect many valuable lessons have been learned that are now applied to touring-car practice. The comfort and safety of the driver must not be overlooked, for an uncomfortable driver cannot conserve his energy and strength for the exacting demands of race piloting.

Why Not an Economy Test?

Mr. Duesenberg predicted that the 1923 Indianapolis race would witness surprising revelations of high efficiency and maximum power. He wondered whether it would not be of material advantage to the industry if some form of economy test or competition could be arranged. At present, very little thought is given to economy in the design of racing engines; maximum power and speed are the only essential requirements.

One great difficulty met in racing engineering is the unreliable reports that the drivers often give of a car's performance and faults. Very often these lead to design changes that are unnecessary and unsound. It is often difficult to trace down the fundamental reason why one car is faster than another. When alterations or adjustments are made, they are seldom made one at a time, so that it is next to impossible to trace the improved performance to any one particular change. Block testing to attain the maximum engine performance is not always reliable. Mr. Duesenberg cited an example where one of his engines had been removed from a car that was acceptably fast, and this engine put on the dynamometer to improve its power output. The power was increased from 84 to 115 hp. by altering the timing, the manifolds, the carbureter adjustment and the lubricating oils. When the engine was again placed in the racing chassis it became necessary to alter all of the block test adjustments to attain a satisfactory performance, but, in the end, the performance was bettered due to certain of the changes that had been made as a result of the dynamometer study.

Unsprung Weight and Large Tires

The reduction of the unsprung weight is important in racing cars. Reducing the weight of the rear axle 25 lb. on one of the Duesenberg cars increased its speed from 118 to 121 m.p.h. In another instance, changing from 34 x 4½ to 33 x 5 tires increased the car speed on the Indianapolis track with a reduction in the engine speed. The cushioning effect of the larger tires prevented slippage and bouncing of the wheels. Mr. Duesenberg credited Jimmy Murphy's Irish grit with a greater part in the winning of the French Grand Prix than the four-wheel brakes with which his car was equipped. Offsetting the crankshaft from the cylinder center ⅜ in. in the opposite direction from that of rotation, was a feature of the Grand Prix cars. This seemed to improve the engine performance at low speeds from 3 to 4 per cent. Murphy was enthusiastic about this feature after the completion of the race.

Mr. Duesenberg's racing experience has shown him that manifold forms have much to do with the engine compression. He cited tests where changes in the length of the extension pipes on the bottom of the racing carbureters had materially reduced the engine compression. Without the tube in place, a maximum compression of 89 lb. was reached at 3000 r.p.m. Replacing the extension tube reduced the compression at this speed to 79 lb.

New Section Officers

The Indiana Section elected its officers for the year 1923-1924 at this meeting. F. F. Chandler becomes chairman; O. C. Berry, retiring chairman, will serve as vice-chairman; Dan Teetor continues as treasurer; and George Briggs brings his enthusiasm and energy into the duties of secretary.

SUMMER MEETING THIS MONTH

Spring Lake, N. J., Scene of Popular Medley of Technics and Sports

The stage is all set at Spring Lake, N. J., for one of the most successful meetings ever held by the Society. If responses to the formal announcement be taken as an indication of the number of reservations that will be made, one may predict that the 1923 meeting will equal the Summer Meeting attendance record. The first three mails arriving after the distribution of the reservation blanks brought in more than 200 applications for rooms. The end of the first week witnessed the passing of the 400 mark. Apparently the seashore, the technical program and the recreational diversions have appealed to a large majority of the members.

All of the details of the Spring Lake program are not settled at this date, but it is possible to make a preliminary and tentative announcement of some of the features. The first day, Tuesday, will be devoted to the meetings of the

Hotel Monmouth, the Society's Headquarters for the Summer Meeting

Standards Committee and a thorough discussion of the recommendations that will be made by its various Divisions. Those who are not involved in the actions of the Committee can become acquainted with the boardwalk, the beach or play their qualifying rounds in the big Society Championship golf tournament. The semi-annual business meeting of the Society will be held in the evening, when the members will be addressed by President Alden and the members-at-large of the Nominating Committee will be chosen. Dancing will follow this business session.

Wednesday will be get-acquainted day. The entire day is being reserved for recreational and social activities. The golf tournament will be gotten underway in the afternoon and the tennis enthusiasts will tune up their racquets. The inter-section baseball series will be opened with two games in the afternoon. The shooters of the clay bird will start blazing away at mock pigeons and madame may display that new beach creation specially purchased for the occasion.

Large-Section Air-Cushion Tires

The session on Wednesday evening will be taken up with a paper on large-section oversize tires by James E. Hale, of the Firestone Tire & Rubber Co. Engineers who have driven cars equipped with these so-called balloon or doughnut tires are loud in their praise of the improved riding quality that is claimed for them. Mr. Hale has found many doubts and questions confronting him in the introduction of the air-cushion tire and he is pointing his paper to answer these, in most instances by presenting quantitative data. Three of the large tire companies have agreed to bring cars equipped with the large tires to the meeting and it is likely that a special demonstration of the riding quality of these cars will be scheduled.

Four-Wheel Brake Session

Thursday morning has been set aside for the study of four-wheel brakes. A technical session will be started early in the morning and will include several papers descriptive of representative types of brakes that have reached an advanced stage of development. These descriptions will be given by engineers representing the manufacturer of each particular type of brake. Following the descriptions and the papers, there will be a general discussion of the four-wheel brake subject by several representative passenger-car engineers. The meeting will then adjourn to the roadway in front of the hotels where a demonstration of cars equipped with and without four-wheel brakes will be conducted. These demonstrating cars will also be available throughout the meeting period for personal inspection and driving by the members. Three companies have made definite plans to co-operate in this program to date and others are being solicited.

Thursday afternoon will be devoted to the annual field day of the Society. The running races and field events will be run off on the spacious lawn directly in front of the hotels and bordering the ocean and boardwalk. The program includes events for everyone; old and young, ladies, men and children. A very fine collection of prizes has been purchased and these will be distributed among the skilled performers.

Head-Lamp Glare

The session on Thursday evening will be devoted to a discussion of the troublesome problems encountered in head-lamp illumination. State laws are far from uniform and have caused serious complications in the marketing of cars. Anti-glare legislation is developing rapidly and effective means must be found to eliminate any cause for complaints by State highway officials. This matter will be the subject of a paper by R. N. Falge of the research staff of the General Electric Co. at Nela Park. He will supplement his paper with an outdoor demonstration of head-lamp adjustment, light distribution, glare measurement, special lenses and reflectors. This demonstration will be worth seeing.

The technical session on Friday morning will be devoted largely to the work that has been done during the past few months in carrying on the Society's fuel volatility study at the Bureau of Standards. These tests are the ones being conducted under the joint supervision of the National Automobile Chamber of Commerce, the American Petroleum Institute and the Research Committee of the Society. The recent work has been devoted to studying the effect of decreasing volatility on crankcase-oil dilution and the findings are of engineering and economic importance. Prof. G. B. Upton will also contribute a paper in this session on recent investigations made at Cornell University bearing upon the improvement of fuel economy. The Bureau of Standards staff will bring one or more of their test cars to the meeting for inspection by the members and they are also planning to demonstrate some of their test methods, notably the determination of the degree of crankcase oil dilution.

The Swimming Carnival

Spring Lake boasts of a very fine still water outdoor bathing pool surrounded by large verandas and equipped with diving boards and platforms for fancy diving. The presence of these facilities was not overlooked by those in charge of the athletic program and, as a result, Friday afternoon has been set aside for the Swimming Carnival. Races, plunges, stunts, diving and all manner of aquatic events will be staged. The verandas surrounding the pool will amply accommodate the large gallery that is expected to watch these water sports. The final game of the Section baseball series will be played directly after the Swimming Carnival. Meanwhile, the golfers, the trapshooters and the tennis followers will be battling for the final honors in their respective fields. All champions must be declared by Friday at sundown.

Friday evening will see the closing of the formal program of the Summer Meeting with the Grand Ball and distribution of prizes. The winners of the all round and Section championships will be announced. The dancing contests featured for many years past will be a feature of the Grand Ball.

For the Ladies and Children

There will be plenty of recreational and social features incorporated in the Spring Lake program for the ladies and children. Card parties will be featured when the men are busy with technical meetings or demonstrations. Motion pictures will be run simultaneously with all evening meetings. Dancing can be enjoyed during afternoon tea and will follow each of the evening technical sessions until after midnight. The kiddies will enjoy digging in the sandy beach that is just across the road from both hotels. There will be athletic events in all branches of sport for both ladies and children. Summer meetings beckon to the entire family.

SPRING LAKE ROAD MAPS MAILED

Through the courtesy of the Hyatt Roller Bearing Co., the members of the Society were each provided with a road map showing how to reach Spring Lake from either New York City or Philadelphia. Jersey is very proud of her State highways and motorists are well cared for, along the coast line particularly. A large fireproof garage of modern type is located directly back of the hotels where the Society will be quartered. Folks from the Middle West will find the Lincoln Highway in good condition and this route is recommended as the most direct way to reach Spring Lake from Chicago, Cleveland, Indianapolis and other cities. Detroiters will probably make better time by taking the boat to Buffalo and driving from that point.

REDUCED RAILROAD FARES

Members Can Travel to Summer Meeting at Fare and Half for Round Trip

All members of the Society will receive certificates with the next issue of the *Meeting Bulletin* entitling them to purchase round-trip tickets to the Summer Meeting at Spring Lake for one and one-half times the regular one-way rate. This privilege is limited strictly to members of the Society

RAILROAD FARES AND TRAIN SCHEDULE FOR SUMMER MEETING AT SPRING LAKE, N. J., JUNE 19-23, 1923

From	RAILROAD FARES: Fare and One-Half for Round Trip	RAILROAD FARES: Summer Excursion Rate	PULLMAN FARES: Lower Berth, One Way	PULLMAN FARES: Upper Berth, One Way	PULLMAN FARES: Drawing Room, One Way	PULLMAN FARES: Compartment, One Way	Train Schedule. Special Train Leaves Monday, June 18
Chicago	$48.75	$58.78	$9.00	$7.20	$31.50	$25.50	10:30 a.m.
Detroit	39.12	45.68	7.50	6.00	27.00	21.00	1.20 p.m.
Cleveland	30.55	38.14	5.63	4.50	21.00	15.75	6:05 p.m.
Toledo	36.30	45.68	6.38	5.10	22.50	18.00	3:15 p.m.
Cincinnati	40.20	51.06	7.50	6.00	27.00	21.00	1:45 p.m.
Dayton	37.55	47.52	7.50	6.00	27.00	21.00	2:35 p.m.
Columbus	33.75	42.44	6.38	5.10	22.50	18.00	4:50 p.m.
Buffalo	27.05	29.03	4.50	3.60	16.50	12.75	7:45 p.m.
Pittsburgh	23.75	....	4.50	3.60	16.50	12.75	11:15 p.m.

The S.A.E. Special arrives at Spring Lake Tuesday, June 19, at 9:45 a.m.

and the dependent members of their families. The certificates must be validated upon arrival at Spring Lake and the Society staff is not permitted to pass any certificates presented by persons other than those shown to be members by our records.

The table reproduced on this page shows the rate of fare applying from the principal automotive centers to Spring Lake. It also gives the time of departure of the special Pennsylvania train that will bring the Western delegation to the meeting on Monday, June 18. Reservations on this special train should be made through the Pennsylvania Railroad representative in your city or the Secretary of the Section of the Society nearest you. Pullmans leaving the several cities will be assembled into a special train at Pittsburgh and will run direct to Spring Lake in time for the opening of the meeting, Tuesday morning. Members living in the East can travel to Spring Lake conveniently through Philadelphia and New York City, since trains are operated at frequent intervals to the Jersey coast resorts at this season of the year.

Watch the *Meetings Bulletin* carefully for last minute transportation announcements.

MATHEWSON BUFFALO SECTION CHAIRMAN

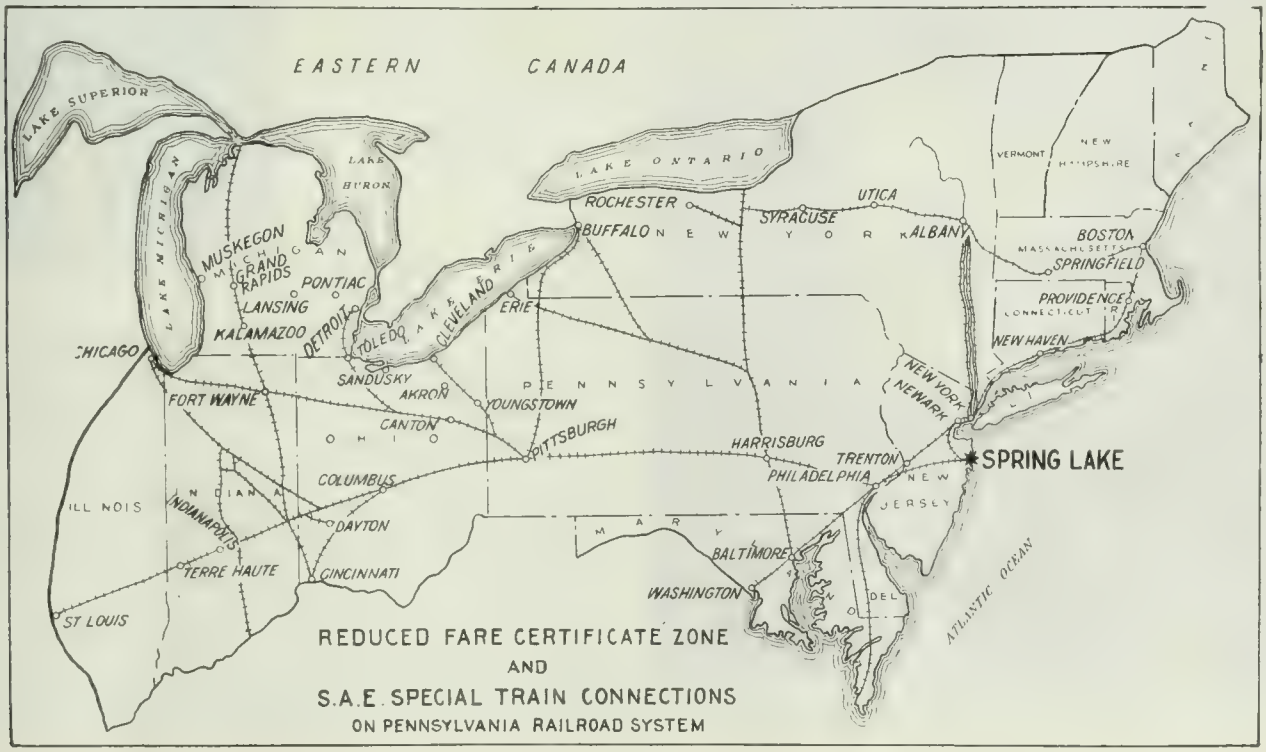
Through an unfortunate error the photograph of Otto M. Burkhardt was printed on p. 507 of the May issue of THE JOURNAL as the newly elected Chairman of the Buffalo Section of the Society. E. T. Mathewson is the Chairman of the Buffalo Section for the year 1923-1924 and not Mr. Burkhardt. However, this provides an opportunity to make proper acknowledgment of Mr. Burkhardt's unusual enthusiasm and active effort in behalf of the Buffalo Section during the year just closed.

CLEVELAND SECTION STAGES FROLIC

Athletes Cavort in Preparation for Spring Lake Inter-Section Contests

The Cleveland Section ended its 1922-1923 year with an out-door frolic and sports carnival on the spacious grounds of Nela Park on May 19. Over 50 members of the Section turned out to display their athletic prowess, and subsequent reports indicate the creation of many sore muscles but no regrets. John Younger and K. B. Britton aroused great enthusiasm among the resident engineers of Cleveland with their cleverly worded and attractively printed announcement of the proceedings. Based on the predictions made therein, one might have expected almost anything. As it was, the contests proceeded on a friendly basis without injury or fatality.

Following a brief business session, several races were run for the youthful and more ambitious members. These were followed by less exacting tests of skill such as broad jump-



L. L. Williams Secretary | O. A. Parker Vice-Chairman | John Younger Chairman | Harry Figgie Treasurer

THE 1923-1924 OFFICERS OF THE CLEVELAND SECTION

ing, high jumping, shot put and three-legged sprints. L. L. Williams, best remembered for his direction of and participation in the Cleveland Circus at West Baden, staged a golf driving contest but substituted a wooly pellet for the more attractive rubber sphere. The contest attracted several who were uninitiated to the Vardon swing and provoked much merriment at the expense of the contestants. G. H. Madelung, designer of air-gliders, conducted a balloon race that provided time and opportunity for those who wished to blow themselves unto the bursting point.

Harry Figgie, famed underhand hurler of the indoor baseball, marched his choice for Spring Lake onto the ball diamond and challenged all comers. This particular ball game proved to be one worth watching, but hardly conducive to an even temperament on the part of the participants.

Figgie's followers lived up to their reputations and the all-comers were appropriately buried with scientific honors. Babe Ruth Buckwalter swung his bludgeon mightily and Harry Portugal shouted effectively for the winners.

Events of the day were announced to the assembly by K. B. Britton in the role of town crier and general disturber. His costume reflected originality to say the least, but the bell he tolled broadcast the identical refrain of the well-known summoner to the dining board and, in this instance, the latter was only represented by a lone hot-dog wagon whose bill of fare was decidedly limited in variety.

All in all, it was a big day and thoroughly enjoyed by those present. Officers for the year 1923-1924 were elected at the outing. John Younger, who has served as an efficient chairman of the Meetings Committee of the Section, was chosen chairman. Orrel A. Parker, retiring chairman, becomes vice-chairman; Harry Figgie remains as treasurer; and L. L. Williams shoulders the responsibilities of secretary. A substantial balance was reported on hand in the treasury for the conduct of an active program of meetings in the fall.

K. B. BRITTON ANNOUNCING THE VARIOUS EVENTS AT THE CLEVELAND SECTION'S PICNIC

SPRING-SUSPENSION AND SPRING MATERIALS

R. E. Northway Discusses Types and Methods of Treatment at New England Section

R. E. NORTHWAY

At the meeting of the New England Section in Springfield, Mass., on May 17, R. E. Northway, president of the Northway Motors Corporation, described types of spring-suspension for automobiles and discussed the materials available and the treatment found satisfactory in producing reliable springs.

The designing of a set of springs that will be satisfactory has always been more a matter of good judgment and experience than calculation. There are so many unknown quantities in the bringing out of a new model that the best of engineers have found it advisable, after making their calculations, to consult practical spring-makers and have several sample sets made up and tried out under varying loads and road conditions before approving the design.

During the past 25 years, the automobile industry has tried out not only every type of spring-construction and suspension existing previous to the advent of the automobile, but also many new types that have been designed during this period. Many auxiliary devices have also been designed to assist or control the action of springs. Some of these devices are really good and do help to overcome the faults of poor spring design and construction; but to insure good riding qualities, long life and good performance on the road, springs must be designed properly and constructed of suitable material that has been properly worked from the blast furnace to the finished spring.

Only Leaf Spring Stands Test of Time

The laminated or leaf spring in its various forms is the only type that has stood the test of time. In the early days of automobile development, many types of coil spring were tried out, some arranged to carry the load in suspension, some in compression. These were soon discarded, however, for it was found that they were as expensive as leaf springs and required a dash-pot or restricted air-control device to be satisfactory.

The prevailing types of leaf springs are the quarter-elliptic, half-elliptic, three-quarter-elliptic and full elliptic. The three-quarter plate form was used up to 1910 or 1911, but is not in use today, and the full-plate form is practically impossible to use. The full-elliptic spring, when properly designed and suspended, gives excellent riding qualities, but it has been practically discarded, although one of the oldest automobile companies in the United States, with a car known for its good riding qualities, has always used it.

Today the quarter and the half-elliptic in their various forms of suspension are the popular types of spring. A study of the cars using them shows that the quarter-elliptic is almost exclusively confined to the low-priced car. When properly designed and constructed, there is no doubt that this type will give excellent riding qualities at a low manufacturing cost. For heavy-duty high-grade cars, on the other hand, there is no doubt of the popularity of the half elliptic. Of the 109 companies listed as exhibitors at the New York City show this year, 85, or 78 per cent, were using half-elliptic springs suspended in the conventional manner, 2 or approximately 2 per cent, were listed as using the quarter elliptic and the remaining 20 per cent were divided among the other types.

It is Mr. Northway's opinion that the cantilever type of suspension, quarter-elliptic cantilever, half-elliptic cantilever and double quarter-elliptic cantilever is at a standstill. Of course every type of suspension has its advocates, but a careful study of manufacturing costs and operation on the road, indicates that the standard half-elliptic spring, fastened to the axle approximately in its center, bolted to the frame at its front end and shackled to the frame at the rear end, is the most economical to manufacture and can be made to have all the good riding qualities of any of the other types of suspension without dangerous side-sway at high speeds.

Usually it is necessary to have an entirely different set of springs for a closed car, and sometimes it is advisable to make a slightly different spring for the right front spring, on account of a heavy engine-torque.

Fundamentals of Spring Design

In summing up the fundamental principles of spring design, Mr. Northway listed these as essential:

(1) A long spring is more flexible and easier riding than a short one

(2) A spring should carry its normal load without much camber, that is with the main leaf practically straight.

(3) The maximum safe deflection is dependent on the thickness of the main leaf and the elastic-limit of the material used.

(4) A spring made of thick leaves will be stiffer than one made of thin leaves, although both carry the same load

When the question of what material is to be used has to be decided, many things have to be taken into consideration. The terms carbon steel, vanadium steel, silico-manganese steel, chrome vanadium and many registered trade names are meaningless unless coupled with the reputation of the steel-maker and the spring-maker for uniformity of material and workmanship.

An alloy-steel having a fine chemical analysis in spots but lacking uniformity will never make a good spring. A steel that shows a good uniform chemical analysis can be spoiled in working or heat-treating. An alloy-steel improperly handled will not make as good a spring as a high-grade carbon-steel formed and heat-treated correctly. Therefore, to produce good springs it is not only necessary to select good materials and have a good design, but it is absolutely essential to select a good spring-maker to look after the details.

Mr. Northway closed his talk with a detailed description of the old guess-work way of spring-making, as contrasted with the carefully controlled modern methods.

In the discussion that followed, a number of new points were developed. In answer to a question put by Mr. Abell, Mr. Northway said that for easy riding it is advisable to keep the rate of vibration of a spring below 90 per min. He could not, however, say whether it was well to reduce it to 50, the rate of vibration of an English spring about which Mr. Abell had inquired.

Asked whether there was a different ratio between the front and the rear springs, Mr. Northway answered that, although it is necessary to adapt the method to the individual model, he had sometimes found it necessary to make a stiffer front spring, to hold the machine in the road. A shorter front spring is needed for the same reason.

The Department of Commerce film, the Story of Alloy-Steel, followed Mr. Northway's talk.

The officers of the New England Section for the coming year will be: Chairman: R. E. Northway; Vice-Chairman: E. O. Sutton; Secretary: V. A. Nielsen; Treasurer: Linwood H. Young. Mr. Nielsen will be the New England delegate on the 1924 National Nominating Committee.

OBITUARY

H. S. McDewell, research engineer for the Maxwell Motor Co., Detroit, Mich., died suddenly at his residence in the City of Washington, April 6, 1923, aged 37 years. He was born at Winthrop, Mass., July 9, 1885. After graduating from Phillips Exeter Academy, he entered Harvard University in 1903 and was graduated with the class of 1907 from the mechanical-engineering course in the Lawrence Scientific School. In 1908, upon completion of post-graduate work in internal-combustion engineering at the Graduate School of Applied Science, of Harvard, he received the degree of Master of Mechanical Engineering.

His professional career began in 1908 with the Allis-Chalmers Mfg. Co., Milwaukee, where he became gas-engine erecting-engineer, and was employed in erecting, supervising and redesigning large stationary gas engines of 300 to 6000 b.hp. until 1914. From 1914 to 1917 he was an instructor in internal-combustion engineering and laboratory practice and participated in research work at the University of Illinois. He then became engineer of tests in the aeronautical engine-testing laboratory at the Washington Navy Yard and supervised the testing and development of aeronautical engines and powerplant accessories for a period of about 5 years. Subsequently, his connection was with the Maxwell Motor Co., as stated. He was especially competent in the design, construction and development of large stationary gas engines and gas producers, and of aeronautical engines.

Mr. McDewell collaborated with Prof. L. S. Marks in the authorship of Gas and Oil Engines and Gas Producers, published in an encyclopedia of engineering of the American Technical Society, Chicago, and later included in Bulletin No. 3 issued by the Naval Consulting Board. He also collaborated in preparing the manuscript for the internal-combustion section of the mechanical engineer's handbook issued by the McGraw-Hill Book Co. He was a charter life member of the Association of Harvard Engineers and a member of the American Society of Mechanical Engineers, having been elected in 1908.

He was elected to Service Member grade in the Society April 12, 1919, and was transferred to Member grade, Jan. 9, 1923. Mr. McDowell is survived by his widow and two children, his mother and a brother.

Applicants *for* Membership

The applications for membership received between April 15, and May 15, 1923, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ASHLEY, RAYMOND T., president and manager, Ashley Patents, Inc., *Reno, Nev.*

BAER, W. D., secretary and treasurer, Iron City Spring Co., *Pittsburgh.*

BAKER, B. F., designer, Rock Island Arsenal, *Rock Island, Ill.*

BEELER, WILLIAM R., student, University of Michigan, *Ann Arbor, Mich.*

BLEYLE, C. A., supervisor, Texas Co., *Boston.*

ROSE, SIDNEY, student, Cleveland School of Technology, *Cleveland.*

BOULDEN, H. T., vice-president, Selden Truck Corporation, *Rochester, N. Y.*

COCHRANE, R. A., mechanic, Motor Transit Co., *Los Angeles.*

COLLEY, P. F., experimental engineer, Yellow Cab Mfg. Co., *Chicago.*

COLLINS, J. F., chief engineer, Mitten Traylor, Inc., *Philadelphia.*

COLTRIGHT, P. E., chief chemist and metallurgist, Wisconsin Steel Co., *Chicago.*

CUSTER, LEWITT LUZERN, president and treasurer, Custer Specialty Co., *Dayton, Ohio.*

DONALDSON, W. R., designer, General Motor Truck Co., *Pontiac, Mich.*

DUMAS, PAUL L., editor of readers clearing house, *Motor Age, Chicago.*

DURHAM, CADY B., assistant general manager, Buick Motor Co., *Flint, Mich.*

EDINGER, EDWARD PETER, student engineer, Franklin Automobile Co., Syracuse, N. Y.

GRAY, JOHN S., student, University of Utah, *Salt Lake City, Utah.*

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HANCORD, H. W., student, Iowa State College, *Ames, Iowa.*

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HESS, FRANK J., assistant automotive engineer, Tide Water Oil Co., *Bayonne, N. J.*

HOELL, W. [illegible], manager and superintendent of body shop, International Motor Co., *New York City.*

IRGENS, FINN TRUMPY, student, Purdue University, *Lafayette, Ind.*

JOHNSON, HAYNES H., chief draftsman, Whitehead & Kales Co., *River Rouge, Mich.*

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KELLEHER, R. J., European representative, North East Electric Co., *Paris, France.*

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LEONHARDT, HARRY H., salesman of automotive parts and mechanic, Gray Automotive Parts Co., *New York City.*

LEWIS, JOSEPH CARLETON, service manager, Noyes Buick Co., *Boston.*

LINDEMAN, EDWARD H., sales engineer, Perfection Spring Co., *Cleveland.*

MCCARTHY, J. LUCIEN, automobile mechanic, 776 Green Street, *Cambridge, Mass.*

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MATHEWSON, M. I., expert metal and designing engineer, Detroit Gear & Machine Co., *Detroit.*

MELLEIM, H. W., student, Carnegie Institute of Technology, *Pittsburgh.*

MEYER, FRED C., stock clerk, Uppercu-Cadillac Motor Car Co., *New York City.*

MICHELIN, MARCEL, Michelin & Cie., *Clermont-Ferrand, France.*

MONJAR, J. G., sales representative, Hyatt Roller Bearing Co., *Detroit.*

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O'HAIRE, P. J., foreman machinist, Harrolds Motor Car Co., *Long Island City, N. Y.*

O'HARE, G. DENNIS, research engineer, O'Hara & Smith, *San Francisco.*

PATTERSON, C. W., lubricating engineer, Standard Oil Co. of Louisiana, *Memphis, Tenn.*

PILE, W. D., automobile engineer, Clanwilliam Motor Co., *Dublin, Ireland.*

RANDOLPH, DONALD W., assistant mechanical engineer, Bureau of Standards, *City of Washington.*

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SCHELL, CARL A., engineer, Thermoid Rubber Co., *Cleveland.*

SHARLOCK, HERBERT L., vice-president, Gernandt Motor Corporation, *South Bend, Ind.*

SHIMIZU, YUTARO, New York representative, Yanese Automobile Co., *Tokyo, Japan.*

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VANATTA, JEAN K., mechanical engineer, Mudge & Co., *Chicago.*

WALLER, EINAR, designing engineer, General Motors Corporation, *Detroit.*

WEADICK, ROBERT M., student, Franklin Institute, *Boston.*

WETHERBY, W. G., secretary and treasurer, Handy Governor Corporation, *Detroit, Mich.*

WOOD, WILLIAM G., JR., sales engineer, I. Silver, *Brooklyn, N. Y.*

WOOD, WALTER G., student, University of Utah, *Salt Lake City, Utah.*

YACKEY, GEORGE FREDERICK, student, University of Illinois, *Urbana, Ill.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between April 10 and May 10, 1923. The various grades of membership are indicated by (M) Member, (A) Associate Member; (J) Junior, (Aff) Affiliate; (S M) Service Member, (F M) Foreign Member, (E S) Enrolled Student

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A product of over fifty years distinguished service in the most important electrical fields, possessing inherent characteristics which make it pre-eminently desirable for
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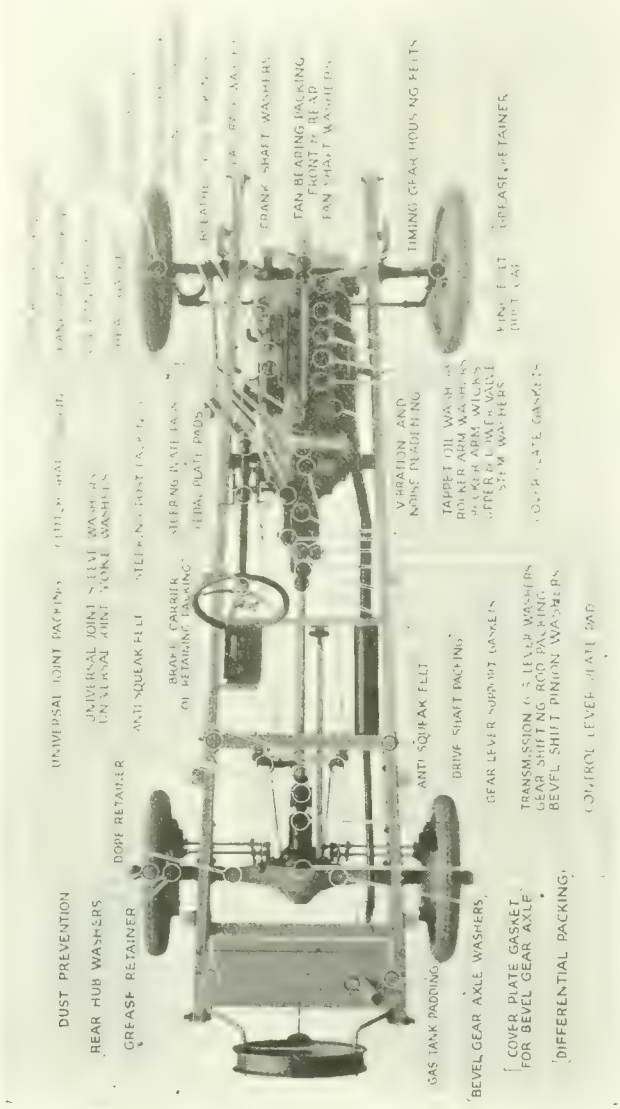
A Trouble Chart



This illustration shows less than half of the places on a typical chassis of current production where practically all automobile manufacturers in the industry have found trouble develop in lubrication—grease retention and dust prevention—and with noise.

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Do you recognize any of the spots indicated above as "weak" points in the car *you* build? Do you want expert assistance in correcting the faults? Our organization is at your service—a letter or call at our nearest office will start the wheels moving for you.

American Felt Company

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BOSTON—211 Congress St.
CINCINNATI—1 Greenwood Bldg.
SAN FRANCISCO—833 Market St.

Personal Notes of the Members

Items regarding changes in business connections, promotions, etc., are desired from the membership for insertion in these columns. This will enable members to keep their friends informed of their whereabouts and will also assist in keeping the records of the Society up to date.

E. C. Arndts has been appointed district sales manager with headquarters at Cleveland for the metal cleaning division of the Crescent Washing Machine Co., New Rochelle, N. Y.

H. A. Best, who until recently was sales representative at Chicago for the Sheldon Axle & Spring Co., Wilkes-Barre, Pa., is now located at the Detroit office of the Spicer Mfg. Corporation, Plainfield, N. J.

A. D. Chandler, who was formerly sales engineer for the Pharo Mfg. Co., Detroit, is now associated with the Beaver Mfg. Co., Milwaukee, Wis.

F. F. Chandler, for many years manager of sales and advertising with the Chandler & Taylor Co., Indianapolis, Ind., has resigned and on May 1 became associated with the Ross Gear & Tool Co., Lafayette, Ind.

Rene L. Cros, who formerly attended the Ohio State University, Columbus, is doing final inspection work at the Delco-Light Co., Dayton, Ohio.

Harry S. Durland, until recently associated with the Wright Aeronautical Corporation, Paterson, N. J., in connection with foundry production and equipment, is now an editorial assistant with *Bus Transportation,* New York City.

Frank L. Eidmann, who returned a short time ago from a trip around the world, as mentioned in the April issue of THE JOURNAL, has been appointed associate professor in mechanical engineering at Princeton University, Princeton, N. J.

Harry Fosdick has been appointed manager of Boston retail sales for the Sills-Chevrolet Co., Boston. He was formerly vice-president and sales engineer for Paul Le Hardy, Inc., Rochester, N. Y.

Herbert A. Goddard has severed his connection with the Sinclair Motors Corporation, New York City, where he was vice-president and director of sales. No announcement has been made of his future plans.

H. B. Griffin, who was until recently associated with the Light Mfg. & Foundry Co., Pottstown, Pa., has accepted a position in the Detroit office of the Doehler Die-Casting Co., Brooklyn, N. Y.

Reno Haibe has become affiliated with the service department of the Cole Motor Car Co., Indianapolis. He was previously master mechanic with the Inglis & Lytle Construction Co., Jacksonville, Fla.

John J. Henry, who was until recently engineer in charge for the Bethlehem Motors Corporation of New York, Pottstown, Pa., has become chief inspector for the Ward Motor Vehicle Co., Mt. Vernon, N. Y.

(*Continued on p.* 4)

DIXON'S 677

is an economical Transmission and Rear Axle Lubricant of exceptional long life.

Its use means that original factory adjustments of transmission and rear axle may be maintained for a greater period of time because of this long life.

The use of a short-life lubricant presents the necessity of changing factory adjustments with the possible danger of not getting the proper alignment of parts.

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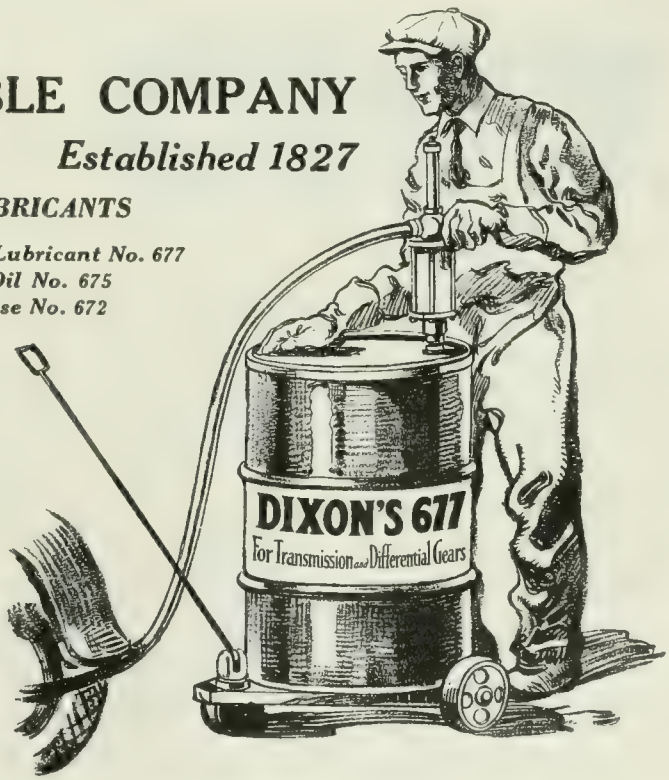

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Gar Wood

Built by "Gar Wood"

Friction losses and lubrication problems are insignificant with only three moving parts—a piston and two pump gears—at all times working in oil, in

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Sales and Service in Principal Cities

PERSONAL NOTES OF THE MEMBERS

Continued

J. Q. Holmes has joined the process department of the Remy Electric Co., Anderson, Ind. He was formerly engaged in experimental work with Robert H. Hassler, Inc., Indianapolis.

C. L. Huening, who was previously in charge of the specification department of the Mitchell Motors Co., Inc., Racine, Wis., has joined the engineering department of the Auburn Automobile Co., Auburn, Ind.

J. J. Kohl, who was at one time assistant manager of the City Machine & Tool Works, Dayton, Ohio, and more recently general manager of the Vulcan Tool Co., also of Dayton, and **M. T. Ahlers,** formerly assistant chief engineer of the City Machine & Tool Works, and later production engineer of the Columbus Auto Parts Co., Columbus, Ohio, have organized the International Tool Co. with a shop at Dayton.

Kenneth M. Lane has accepted a position as aeronautical engineer with the Wright Aeronautical Corporation, Paterson, N. J. He previously held a similar position with the Dayton Wright Co., Dayton, Ohio.

S. Vance Lovenstein, president and general manager of the Schwarz Wheel Co., Philadelphia, joined the Eugene McGuckin Co., also of Philadelphia, as vice-president on June 1.

Dorr Miller is connected with engineering and sales for the Q & C Co., New York City. Prior to this he was an engineer for the Toledo Automotive Products Co., Toledo.

H. L. Montanya, who was formerly chief inspector for the Yard-O-Meter Corporation, St. Louis, has accepted a position as general foreman of the tools, dies, jigs, fixtures and special machinery departments of the Columbus Die Tool & Machine Co., Columbus, Ohio.

J. G. Murphy has severed his connection with the Anderson Motor Co., Rock Hill, S. C. No announcement has been made of his future plans.

L. F. Nielsen, manager and mechanical engineer of the Equitable Engineering Co., announces the removal of the offices of that company from 103 First Avenue, North, to 15 Wilder Street, Minneapolis.

F. H. Norton, who was formerly chief physicist for the National Advisory Commission for Aeronautics, Langley Field, Va., is now affiliated with Massachusetts Institute of Technology, Cambridge, Mass.

Sidney Oxberry, for the past 4 years art editor of *Motor,* New York City, has resigned and sailed for an indefinite stay in England. Prior to his association with *Motor* he was a member of the editorial staff of *Automotive Industries.*

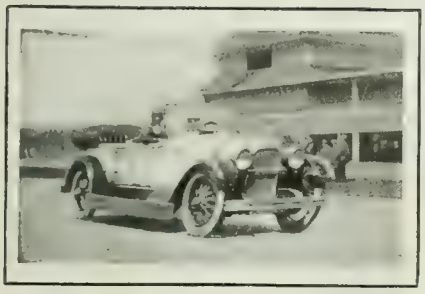
E. F. Paepper, who was an engineer for the Yellow Cab Mfg. Co., Chicago, has been promoted to the position of assistant chief engineer.

Etienne Planche has resigned as chief engineer of the Dort Motor Car Co., Flint, Mich., a position he has held for the past 9 years. He has opened an office as consulting engineer in the General Motors Building, Detroit.

R. C. Plexico has accepted a position as assistant engineer and chief draftsman for the Warner Gear Co., Muncie, Ind. He was formerly assistant chief engineer for the Anderson Motor Co., Rock Hill, S. C.

(*Continued on p.* 6)

The Duesenberg Straight Eight, regular stock model, immediately after the Record-Breaking Performance



(1) *Speeding away to the remarkable Record*

(2) *Taking on oil and fuel at fifty miles an hour!*

(3) *Crossing the finish line. Another American Record!*

A Duesenberg Stock Car World's Record With S. R. B. Bearings!

New World's Record Stock Car Endurance Run, 3155 miles in 50 hours 21 minutes and 1 second! Non-stop

Average speed 62-63 M.P.H.

Indianapolis Speedway, April 27-29, 1923

A GRINDING, grueling test putting a terrific strain upon every moving part!

Sturdy S. R. B. Bearings, both Double and Single Row, taken from Duesenberg regular stock, bore the brunt of friction attack at nine important points:

Front Axle, inner	S. R. B.
Front Axle, outer	S. R. B.
Clutch Release Bearing	S. R. B.
Transmission Rear Main Shaft	S. R. B.
Propeller Shaft	S. R. B.
Pinion Shaft, front (double row)	S. R. B.
Pinion Shaft, rear (double row)	S. R. B.
Differential Carrier (2)	S. R. B.
Wheel Bearing Rear Axle	S. R. B.

SRB

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OPERATING UNDER CONRAD PATENTS

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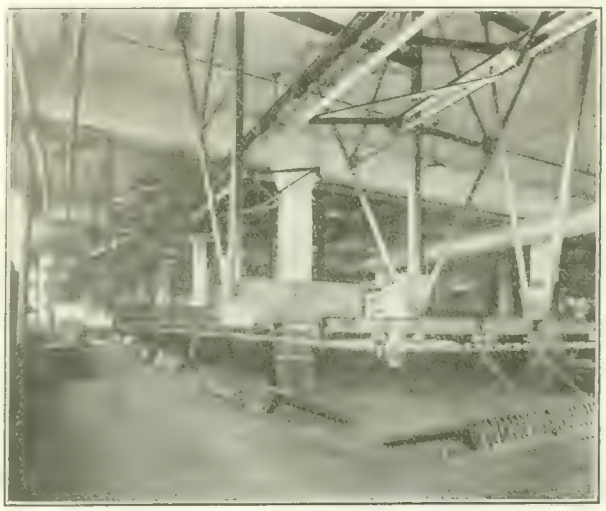
S. R. B. Bearings are serviced by the branches of the Standard Sales and Service Co. throughout the United States



A Section of Windshield Conveyor installed at Ternstedt Mfg. Co. Detroit. Aids in the production of 50 00 Windshields in 8¾ hrs.

Equipment That Cuts Labor Costs in Half

This is an example of the service rendered by The Jas. F. Miller & Hurst Corporation.

In the design and construction of the Windshield Conveyor illustrated above we successfully solved a problem in quantity production at reduced labor and operating costs. A crying need in the automotive industry to-day.

The whole conveyor is 1200 feet long, yet so nicely balanced and adjusted that it carries 3000 Windshields per day through a series of baking and enameling ovens as well as dip tanks and other processes—all this on less than 1½ H. P.

The design of the equipment in this plant has reduced expensive hand labor by half—has materially lowered stock-in-process investment and has established another record for low production costs.

Our experience in planning for greater profits in the largest foundries and industrial plants in the automotive industry is available to you.

Let us show you how similar practices and installations will increase production and decrease costs in your plant.

Write for further information on "Modern Production Methods."

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Quantity Production Foundries and Industrial Plants

GENERAL MOTORS BUILDING
DETROIT, MICH.

PERSONAL NOTES OF THE MEMBERS

Concluded

Alfred J. Poole has severed his connection with the Simms Magneto Co., East Orange, N. J., where he was sales manager. No announcement has been made of his plans for the future.

Finley R. Porter has become associated with the Humphreys Oil Co., Mexia, Tex.

I. D. Rocap, a partner in the firm of Lynch & Rocap, City of Washington, announces a dissolution of the partnership after a sale of the business. His future plans have not been announced.

Porter E. Stone has become affiliated with the Highland Body Mfg. Co., Cincinnati.

Charles H. Tavener, who was formerly agent for the Adams Trailer Corporation, Garden City, N. Y., has been appointed production manager of the Liberty Electric Corporation, Port Chester, N. Y.

George J. Thomas is no longer chief engineer for the Duplex Truck Co., Lansing, Mich., but has become affiliated with the Power Truck & Tractor Co., St. Louis.

H. E. Thompson has accepted the position of chief engineer with the H. E. Thompson Co., Indianapolis. He was formerly job engineer for the Standard Oil Co., El Segundo, Cal.

Joseph C. Towler is now associated with the Packard Motor Car Co. of Boston, Worcester, Mass., doing testing, trouble-shooting and electrical work. He was formerly service manager in charge of service and repair work for the Autolec Co., Inc., also at Worcester.

Erwin A. Weiss has resigned from the Mitchell Motors Co., Inc., Racine, Wis., where he was assistant chief engineer, and is now connected with the engineering department of the Yellow Cab Mfg. Co., Chicago.

S. P. Welch, who was formerly connected with the sales department of the R. H. Long Motors Co., Newark, N. J., has been appointed sales manager with headquarters at Elizabeth, N. J., of the Regina Corporation, Rahway, N. J.

F. M. Young has been elected vice-president and general manager of the Racine Radiator Co., Racine, Wis., which has succeeded the Perfex Radiator Co., also of Racine, with which Mr. Young was previously associated as manager.

THE BANTAM BALL BEARING CO.

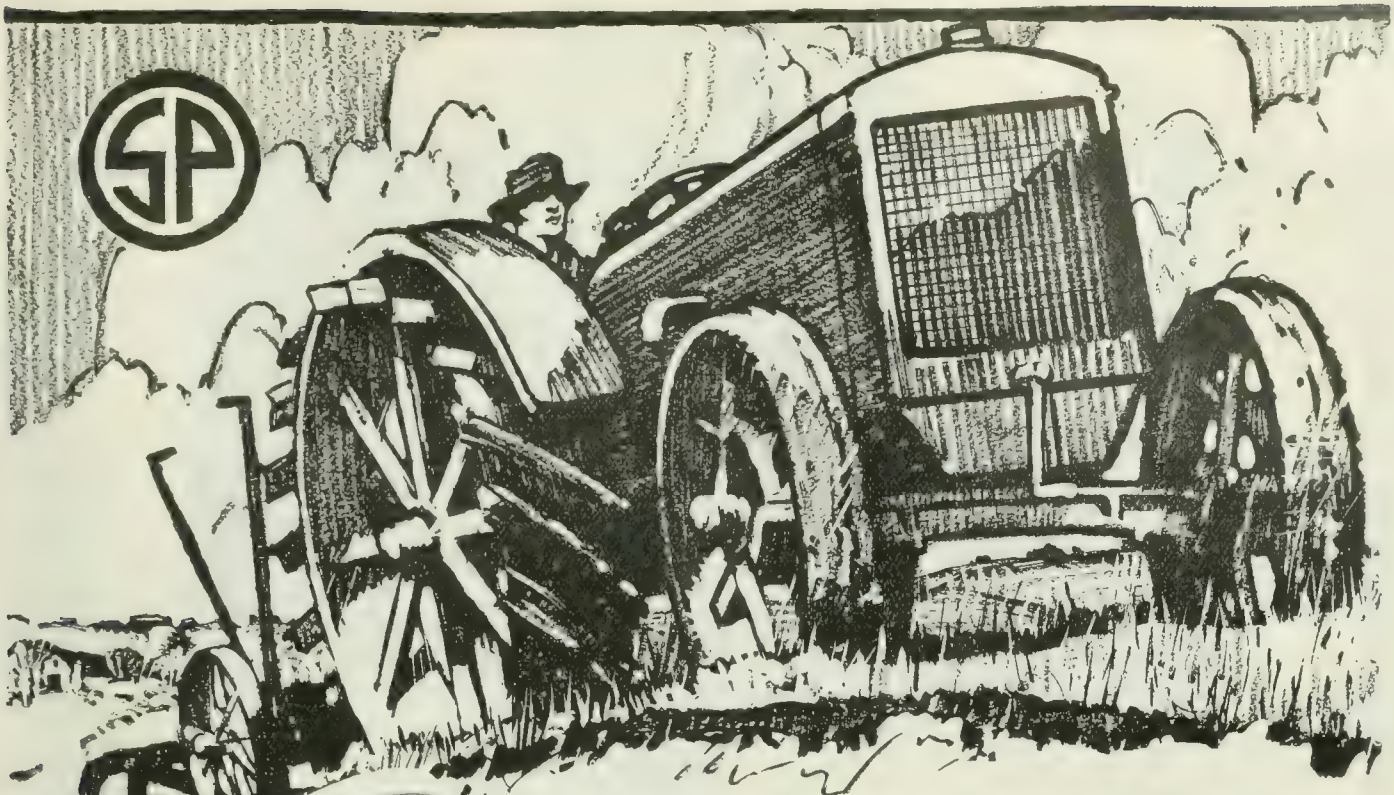
BANTAM, CONN., U.S.A.

Thrust Bearing Specialists

Bearings Made To Your Requirements

DETROIT OFFICE:
905 Dime Bank Bldg.
Detroit, Mich.

PACIFIC COAST:
Frank M. Cobbledick Co.
1031 Polk St., S. F., Cal.



For motors with big jobs to do

There are 400,000 tractors in use on farms of the United States. Total value of 1922 farm crops, $8,961,000.000. Total value of all farm property, $77,924,000,000. Total number of farms 6,448,343

IN the performance of the great tasks of industry, when motors must work under conditions of prolonged abnormal strain, the indestructibility of *Thompson Silcrome Valves* becomes most evident.

Red-hot temperatures which burn away the seats of other valves have no effect on valves of *Thompson Silcrome.*

Friction actually quadruples their wear-resistance by a unique process of surface polishing. Internal stresses that cause warping are absent from this steel.

Investigate *Thompson Silcrome Valves.* Put them in test motors. Try to run them to failure. Then specify "*Thompson Silcrome*". For double protection use the *two* words!

Non-burning
Non-warping
Non-scaling
Non-air-hardening
Weigh least
Wear longest
Moderately priced

—built by a "trail-breaker of industry"

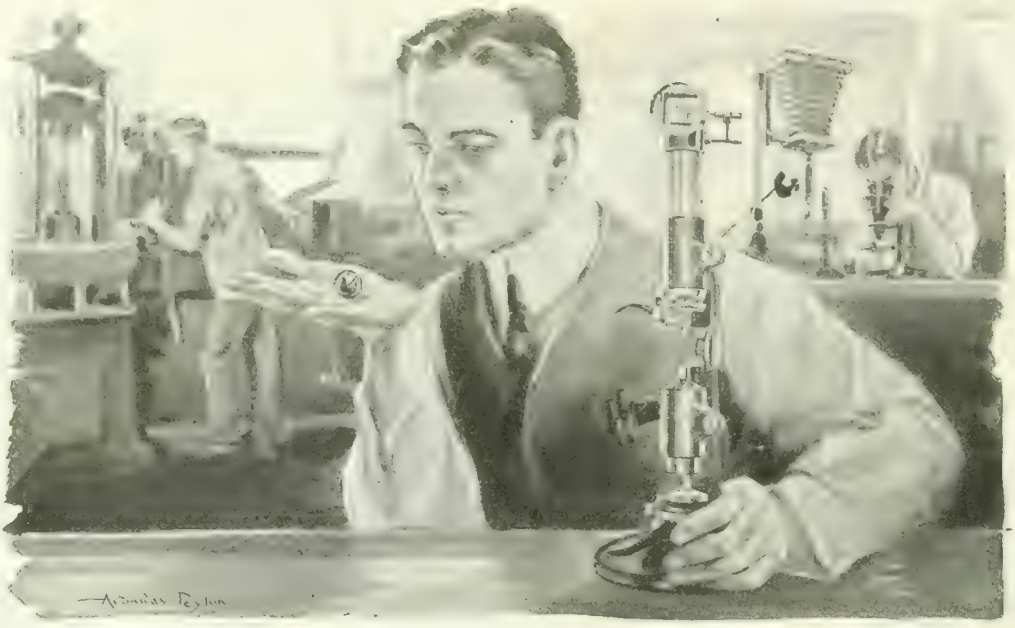
THOMPSON SILCROME VALVES

THE STEEL PRODUCTS COMPANY

MAIN PLANT
CLEVELAND

Also manufacturers of king bolts, shackle bolts, tie rod bolts, drag links, starting cranks, and brake rod assemblies

MICHIGAN PLANT
DETROIT



You Can Cause a Steel Ball of Atlas Accuracy To Register "Off-Size" by Blowing Upon It

RAISING a half inch Atlas Steel Ball to body temperature by holding it in one's hand or by blowing one's breath upon it, is sufficient to cause it to register "off-size" when mixed with others of the same lot held at a room temperature of 70 degrees.

Yet the expansion of a half-inch ball when raised from normal room temperature to that of the body is only about eight hundred thousandths of an inch (.00008″). But Atlas Balls must not deviate from true size by more than five hundred thousandths of an inch (.00005″) generally expressed as one half of 1 10,000″.

With the exception of Johannson gauge blocks such accuracy is seldom equalled or even approached in industrial machine elements. So great is the care exercised in the manufacture and gauging of Atlas Balls that after burnishing they are not touched by hand and are gauged in a room held at a constant temperature.

It is because of this great accuracy, the mirror-like finish and high resistance against fatigue that Atlas Steel Balls have won the enthusiastic endorsement of the most exacting ball users.

ATLAS BALL COMPANY

Glenwood Ave. at Fourth St. - - - Philadelphia

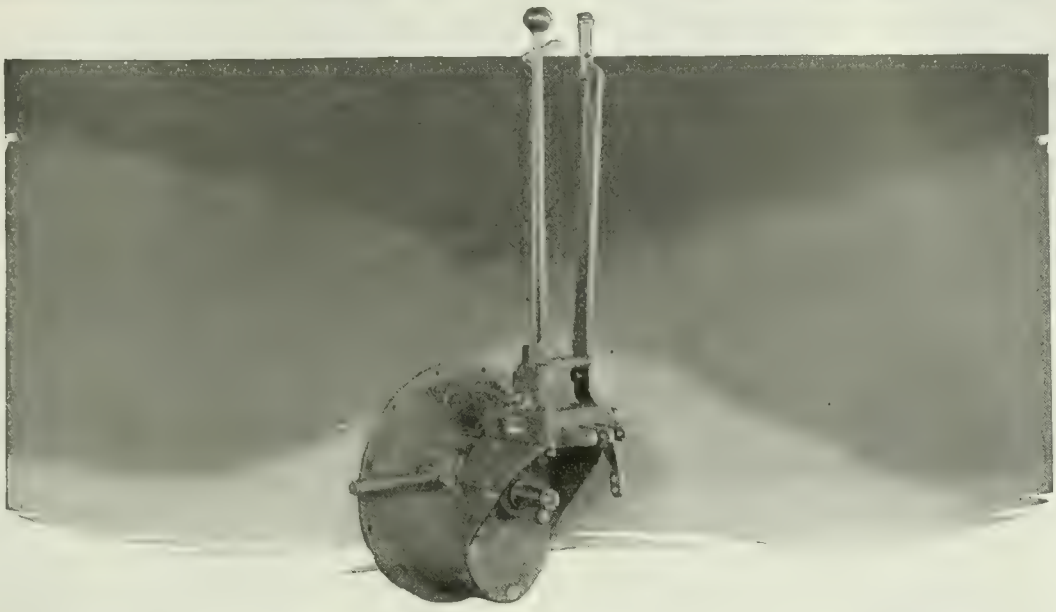
981

ATLAS STEEL BALLS

ALSO BRASS, BRONZE, MONEL AND SPECIAL METALS

Made Under SKF Supervision

SKF



Deep-Groove Ball Bearings on Clutch Shaft Take Both Radial and Thrust Loads

A DEEP-GROOVE ball bearing made by the Hess-Bright Manufacturing Company is used as the rear bearing on this clutch shaft, taking a radial load under normal conditions and a thrust load when the clutch pedal is depressed thereby insuring quietness of operation.

The ability of this type of bearing to take both loads is due to its deep grooves of uniform cross section which permit it to take heavy thrust loads in either direction in combination with radial loads without any impairment of operating efficiency or performance.

No appreciable bearing wear occurs with the result that noise and the expense of bearing adjustments and replacements are avoided. Furthermore, the bearing is a self-contained unit which permits of the ready assembly of shafts and bearings in restructed locations.

Our engineers will gladly submit recommendations for applying ball bearings to clutches and other vital rotating automotive parts.

THE HESS-BRIGHT MANUFACTURING COMPANY

Supervised by SKF INDUSTRIES INC., 165 Broadway, New York City

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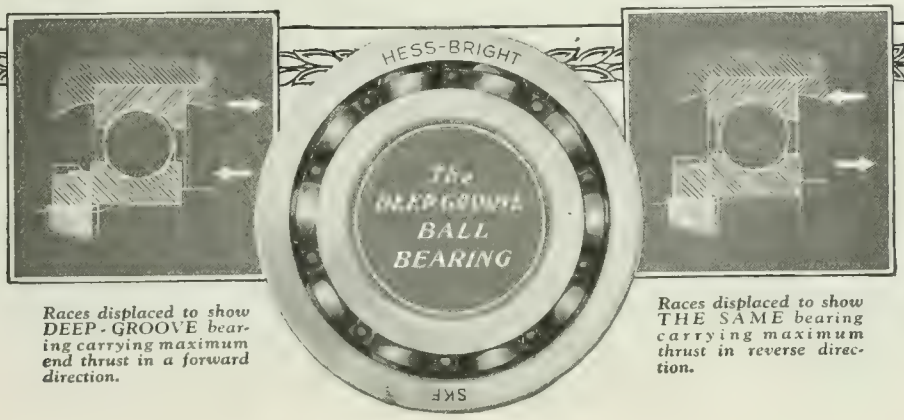


Races displaced to show DEEP-GROOVE bearing carrying maximum end thrust in a forward direction.

Races displaced to show THE SAME bearing carrying maximum thrust in reverse direction.

BALL BEARINGS

The Highest Expression of the Bearing Principle

KELLY SPRINGFIELD AIRCORE

Why the Aircore Tire Should Not Be Overloaded

The Kelly Aircore double-cushion truck tire has been proved by tests to be practically as resilient as a properly inflated pneumatic—yet when properly applied and used, it will have longer life than the average of the solid type of truck tire.

There are certain conditions, however, which must be observed in order to obtain the best results from the Aircore and one of these is, that it *must not be overloaded.*

Owing to the fact that the Aircore is of the high profile type and its spearhead core allows considerable deflection under load, its capacity for a given base width is not as great as would be the case if it were a non-resilient solid rubber tire. It will be readily understood that excessive loads would create excessive deflection of this tire—a condition which, of course, is not conducive to long life.

The design of the center core has been carefully calculated to permit certain maximum loads on various sizes, and it is only when these load limits are carefully followed that the full resiliency, long life and certainty of service of the Aircore can be obtained.

The following table shows the maximum weights to which loads should be limited on Aircores of various sizes:

Size of Aircore	Maximum Weight
4 inches	1300 pounds
5 inches	1700 pounds
6 inches	2500 pounds
7 inches	3500 pounds
8 inches	4500 pounds
9 inches	5000 pounds
10 inches	6000 pounds

Kelly-Springfield Tire Co.
250 West 57th Street New York

Notes and Reviews

In this column are given brief items regarding technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

THE HIGH-COMPRESSION HIGH-SPEED ENGINE VERSUS THE LOW-COMPRESSION MODERATE-SPEED ENGINE FOR GENERAL USE IN MOTOR VEHICLES. By H. R. Ricardo and F. Strickland. Papers presented before the Institution of Automobile Engineers in *Engineering*, Nov. 17, 1922, p. 627.

The Institution of Automobile Engineers, recognizing that the advocacy of very high-compression high-speed gasoline engines is becoming increasingly common, organized a debate on this subject, which was held in London, on Nov. 8, 1922. The merits of the high-speed type were discussed by H. R. Ricardo, who based his argument mainly on the increased fuel economy to be secured by its use; the smaller and lighter pistons and reciprocating parts and the increased turbulence effected by smaller valves. Major F. Strickland, in supporting the claims of the low-compression moderate-speed engine, maintained that the improvement noted in the steam engine with an increase of speed was due to causes that do not obtain in the case of the internal-combustion engine, the parts of which on account of inertia forces, must be increased in size as the speed is increased, and that among the advantages of low compression and moderate speed are less piston and cylinder-wear, simplicity and certainty of operation of the lubricating system and freedom from noise.

AUTOMOBILE CHASSIS. By Ben G. Elliott. Published by McGraw-Hill Book Co., New York City. 233 pp.; 233 illustrations.

Professor Elliott's book is designed to serve as guide and reference book on all parts of the gasoline automobile except the powerplant and its immediate accessories and the body. Fundamental principles are emphasized and these are illustrated by many examples from modern practice. The construction, purpose, operation, adjustment and care of springs, axles, the steering-gear, clutches, transmissions, differentials, bearings, wheels and rims, tires, brakes and chassis lubrication are fully covered.

GRINDING: WHEELS, MACHINES, METHODS. Information on modern practice in the production and application of abrasives, grinding wheels and grinding machines, compiled by members of the executive and technical staffs of the Norton Co., Worcester, Mass., and published by the company, 375 pp.; numerous illustrations and tables.

This book deals in a very instructive manner with modern grinding practice. Examples of processes and machines have been selected chiefly with a view to showing the Norton grinding machines, but the work deals with practically every modern application of precision, semi-precision and hand-grinding.

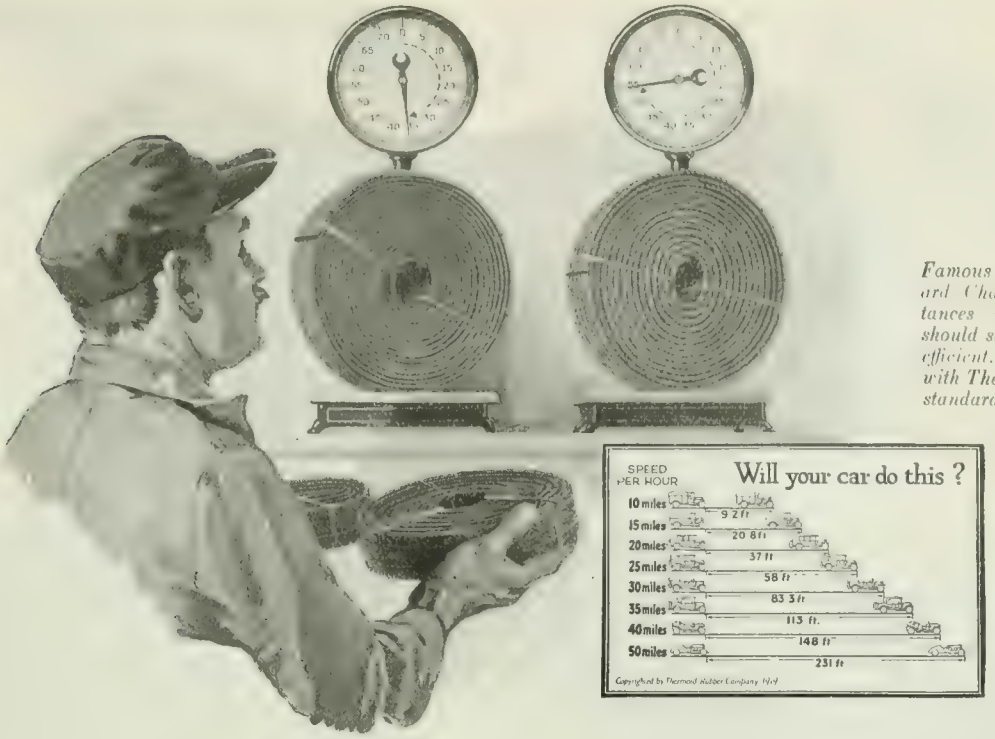
HIGHWAYS AND HIGHWAY TRANSPORTATION. By George R. Chatburn. Published by Thomas Y. Crowell Co., New York City. 463 pp.; many illustrations.

To quote the author's preface, this book is written "for those who desire a conversational knowledge of the origin, evolution and present status of highway transportation, even though it be glimpsed by a very rapid passage through a very large subject." For those who wish to make a more detailed study of the subject the author provides a selected list of references following each chapter.

AUTOMOBILE LABORATORY MANUAL. By Frederick F. Good. Published by McGraw-Hill Book Co., New York City. 174 pp.; 88 illustrations.

The purpose of this outline of experiments is to provide a progressive series of study units in three groups that will serve as a basis for the organization of laboratory automobile classes for beginners. The course covers a systematic introduction to the automobile mechanisms and a study of their fundamental principles and includes practical work and minor repairs.

(*Continued on p.* 12)



Famous Thermoid Standard Chart — shows distances in which cars should stop if brakes are efficient. Brakes lined with Thermoid meet these standards.

"At least 40% extra material"

The new Thermoid Brake Relining Machine. Cuts time 60%—does a better job than old hand methods. Price $15, $17.50 west of the Rocky Mountains. $25 outside of U. S.

Write for special offer to Thermoid dealers.

A simple test which shows the 40% more material in Thermoid Brake Lining

A roll of Thermoid Brake Lining—100 feet—was weighed. The indicator registered 54 pounds, 8 ounces. Then one after another, the rolls of four other leading manufacturers were put on the scales.

Thermoid outweighed each by over 40%!

This means that the motorist gets more for his money in Thermoid than in any other lining. He gets longer wear—by about 40%—and a sure, *even* gripping surface until Thermoid is worn wafer-thin.

Most of the "give" is taken out of Thermoid before it leaves the factory—and *40% more material* is put in its place!

Thermoid *wears* down instead of *mashing* down—it doesn't "grab" or slip. Thermoid gives constant gripping power till worn wafer-thin.

Standard equipment on 50 leading cars

Because of its unfailing, its recognized supremacy and longer life, 50 manufacturers of leading cars in America now install Thermoid Brake Lining as standard equipment.

Send for our booklet, "The Dangers of Faulty Brakes." It contains valuable information and complete records of brake lining tests which every engineer will be glad to have on hand.

THERMOID RUBBER COMPANY

Factory and Main Offices: Trenton, N. J.

New York Chicago Los Angeles Detroit Atlanta
San Francisco Boston Cleveland Kansas City
Seattle London Paris Turin

Thermoid Brake Lining

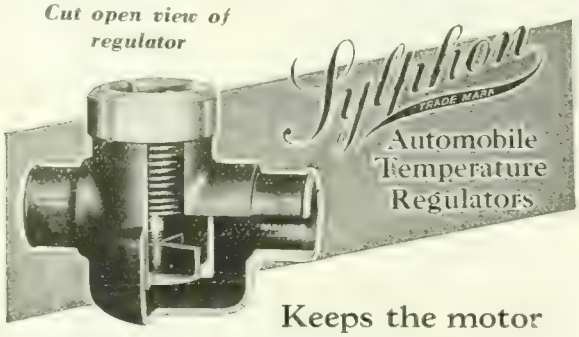
Hydraulic Compressed

Makers of "Thermoid-Hardy Universal Joints" and "Thermoid Crolide Compound Tires"

Standard Equipment
on these Automobiles

American-La France	Lafayette	Roberts
Bay State	Lancaster	Rolls-Royce
Bell	Leyland	Stevens-Duryea
Case	Lincoln	Straker-Squires
Cadillac	Mitchell	Twin City
Climax	Napier	U. S. Tractor
Columbia	Packard	Vulcan Truck
Cunningham	Paige-Detroit	Ward-La France
Kissel-Kar	Pierce-Arrow	Westcott
	Premier	Wisconsin

Cut open view of regulator



Keeps the motor at the degree of highest efficiency

Consists of three main parts: the Sylphon—that seamless, solderless, flexible, all-metal expansion member, which is the heart of all Sylphon products; a valve and a housing for the Sylphon. The Sylphon is filled with a highly volatile liquid, which vaporizes at a predetermined temperature, expanding the Sylphon and opening the valve to admit water and contracting and closing the valve when the temperature falls. It is self-regulating, adapted to pump or thermo-syphon cooling systems, can be installed between the radiator and the engine, either in outlet or inlet water connection. Has no moving parts to wear out, needs no oiling and will outlast the motor. Do not accept imitations or substitutes.

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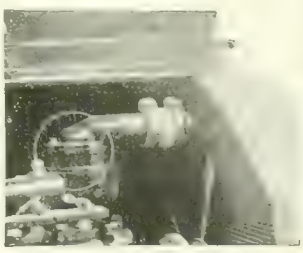
THE FULTON COMPANY
KNOXVILLE, TENNESSEE
New York Chicago Detroit Philadelphia
Representatives in all principal cities

As Installed on Kissel-Kar



As installed on Pierce-Arrow

NOTES AND REVIEWS
Continued

ADVANCED MACHINE WORK. By Robert H. Smith. Published by the Industrial Education Book Co., Boston. 744 pp.; 823 illustrations.

This textbook is a practical manual of machine-shop practice for shops, schools and individuals that has already won for itself a large following in colleges, universities and technical schools, this being the seventh edition. The new section 15 gives practical instruction in making mechanical measurement with light waves to the ten thousandth, hundred thousandth and even to the millionth of an inch.

SEVENTH ANNUAL REPORT OF THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS, including Technical Reports Nos. 111 to 132. Published by the Government Printing Office, City of Washington.

The progress made in scientific research in aeronautics during the year 1921 is described in the reports of the technical subcommittees and exemplified by the technical reports, published during that period, copies of which are summarized in this Report. Attention is especially invited to the Summary of General Recommendations of the Committee, preceding the body of the Report, and setting forth what, in the judgment of the Committee, the most important steps to be taken for the advancement of aeronautics.

A STUDY OF SIDEDRAFT AND TRACTOR HITCHES. By Arthur H. Hoffman. University of California Agricultural Experiment Station. Bulletin No. 349. Published by the University, Berkeley, Cal.

This bulletin was prepared to enable the author to answer in as complete a manner as possible the numerous requests made by farmers for information on various phases of tractor hitching. The application of mechanical principles to agricultural implements is clearly explained and photographic illustrations accompany the text. A valuable list of references to scientific articles and trade publications is included.

PREPARATION OF LIGHT ALUMINUM-COPPER CASTING ALLOYS. By R. J. Anderson. Bureau of Mines Technical Paper No. 287. Published by Government Printing Office, City of Washington.

The author says in his introduction: "In the United States the consensus of opinion among foundrymen is that the alloy containing 92 per cent of aluminum and 8 per cent of copper is the best alloy available for general casting purposes and for some special castings. In addition, more or less definite light alloys have been developed for particular uses, notably piston and carbureter alloys and alloys for so-called leak-proof parts." The process of manufacture of this alloy is described as well as the methods used in preparing various alloys. Twenty-two pages are devoted to description of a number of interesting experiments made in the preparation of rich alloys, and a short list of publications available for free distribution to those interested in aluminum and its alloys follows.

PRINCIPLES OF VEHICLE SUSPENSION. By H. S. Rowell. Published in *The Automobile Engineer*, April, 1923, p. 118.

Abstract of paper read before the Institution of Automobile Engineers.

FURTHER ALCOHOL FUEL DEVELOPMENTS. Published in *Motor Cycling*, London, April 18, 1923, p. 772.

This short article describes the special fuel, Ricardo-Discol, patented by H. R. Ricardo, which is to be placed on the market in England shortly at 6 shillings per gal. At this price the new fuel is of little interest to the ordinary driver, at present, but further developments may remove the price barrier.

Ricardo-Discol is a mixture having an alcohol base. The exact composition cannot be stated, but the following typical example, taken from the patent specification, is near enough for all practical purposes:

Ethyl Alcohol, per cent	60
Acetone, per cent	20
Benzol, per cent	10
Water, per cent	10

(*Continued on p.* 14)

Lockheed Success Recognized by the Industry

Engineers and others whose business it is to keep informed on the trend of motor car development, recognize the success of Lockheed Hydraulic Four Wheel Brakes.

In this device they see the ultimate in brake application—a highly and continuously efficient brake for each wheel, simple in design, rugged in construction, which obviates, once and for all, the necessity of frequent readjustment heretofore experienced.

During the last five years Lockheed Hydraulic Four Wheel Brakes have had the most complete and rigorous test of all, under every conceivable condition.

This is their use by approximately 1000 motor car owners.

Some of the cars on which Lockheed Hydraulic Four Wheel Brakes are used have covered more than 50,000 miles.

Most of these brakes have been, and are being, used in mountainous regions, where they have given the most amazing results.

A Leading Feature on 1924 Models

It is obvious, of course, that the sudden spontaneous demand,—such as that which occurred when the self-starter first sprang into public favor—will place those manufacturers who early decide upon this new equipment, in a position of production advantage.

The fact that 12 manufacturers have sought the close co-operation of the Hydraulic Brake Company, and are now purposing the use of these brakes, is intensely significant.

Four wheel brakes will be one of the chief, and probably *the* chief, new chassis feature of 1924 production.

There are two reasons for this. One is the fact that present brake systems are recognized as inadequate, particularly under the more severe driving conditions which now confront the motorist.

Another, and extremely important reason, is the stiffer competition which strongly brings out the sales value of such equipment as Lockheed Hydraulic Four Wheel Brakes.

A New Experience for the Motorist

It has been demonstrated time after time, and over and over again, that Lockheed brakes make a motor car much easier to sell. They become, in fact, the main feature of a demonstration, and one of the principal selling points.

The ease and smoothness with which Lockheed Four Wheel Brakes operate; the quickness with which they can stop a car when necessary; the feeling of far greater security which they give to the driver, all supply new and distinct advantages to the motorist.

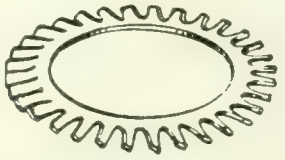
The potential demand for Lockheed Four Wheel Brakes is clearly indicated by the fact that on a motor car where their special installation caused a substantial increase in price, the Lockheed equipped cars sold 100% faster than the non-equipped cars.

We invite inquiries.

Hydraulic Brake Company
700 Harper Ave. Detroit, Michigan

LOCKHEED
Hydraulic Four Wheel Brakes

It's the Engineer's job to make the car BETTER



Few startling changes occur in automobile construction these days, but every progressive manufacturer is constantly on the lookout for minor improvements that will better his product.

Loosened nuts result in body noises; lost bolts or nuts hasten wear. Shakeproof lock washers are a distinct improvement. Vibration makes them lock tighter.

See Those Locking Struts

From 12 to 30 locking struts set at an angle of 45° immediately engage surfaces top and bottom under vibration, gripping in such a way as to give positive locking. Shakeproof are lighter and stronger than ordinary washers; they exert an even pressure at all points; they do not tend to distort thread; they can be used with shorter bolts; they are easier to handle (cutting labor cost); they do not rust.

From 200 to 500 lock washers are used in auto construction. Insure firm "close knit" construction by standardizing on Shakeproof.

SHAKEPROOF
Screw & Nut Lock Co.
Wrigley Building
Chicago

NOTES AND REVIEWS
Continued

It has been tested on the bench and also in racing work and is said to have proved suitable in all respects.

HIGHWAYS GREEN BOOK. Published by the American Automobile Association, City of Washington. 427 pp.; illustrated with photographs.

The object of the Highways Green Book, of which the 1922 edition is the third, is to combine in one volume a compendium of the outstanding highway activities of the past year and a forecast of the future. The book should be of great value to students of current highway legislation, economics, taxation, progress, construction and maintenance and transportation. Chapters dealing with highway research and highway engineering and transport education are ably treated by recognized highway authorities. Valuable lists of references, of highway organizations, and of county highway bond issues are given in appendices.

SOME REMARKS ON THE SUSPENSION OF VEHICLES. By P. Lemaire. Published in *La Technique Moderne*, April 15, 1923, p. 241.

A mathematical study of suspension problems with special reference to riding comfort.

REVUE GENERALE DE L'AERONAUTIQUE. Published by Librairie Aeronautique, Etienne Chiron, Paris, quarterly. 256 pp.; many figures.

This volume, Vol. 2, contains the following articles of interest to members:

(1) The General Problem of the Airplane. P. and M. Richard. 56 pp.
(2) The Use of Reduction Gears on Aircraft Engines. Capt. G. Lehr. 34 pp.
(3) Use of Wood in Aircraft Construction. (Continued from Vol. 1.) Marcel Monin. 12 pp.
(4) The Development of Gliders. Captain Roca. 11 pp.

THE NORTH-LUCAS LIGHT CAR. By O. D. North. Published in *The Automobile Engineer*, April, 1923, p. 98.

A critical examination of a novel and original design, having the engine located at the rear; a design conspicuous for its good suspension, absence of engine vibration and reduced wind-resistance.

THE EVALUATION OF NOISE. Published in *The Automobile Engineer*, April, 1923, p. 109.

A method of comparing and expressing sound in Unit Terms.

METALLURGY AS APPLIED TO ENGINEERING PRODUCTION. By W. R. Franklin. Published in *Engineering Production*, May, 1923, p. 256.

MICROSTRUCTURE OF PAINT FILMS. By Harold L. Maxwell. Published in *Chemical and Metallurgical Engineering*, May 14, 1923, p. 850.

An attempt to determine the relation between microstructure and protective value of certain paints and pigments.

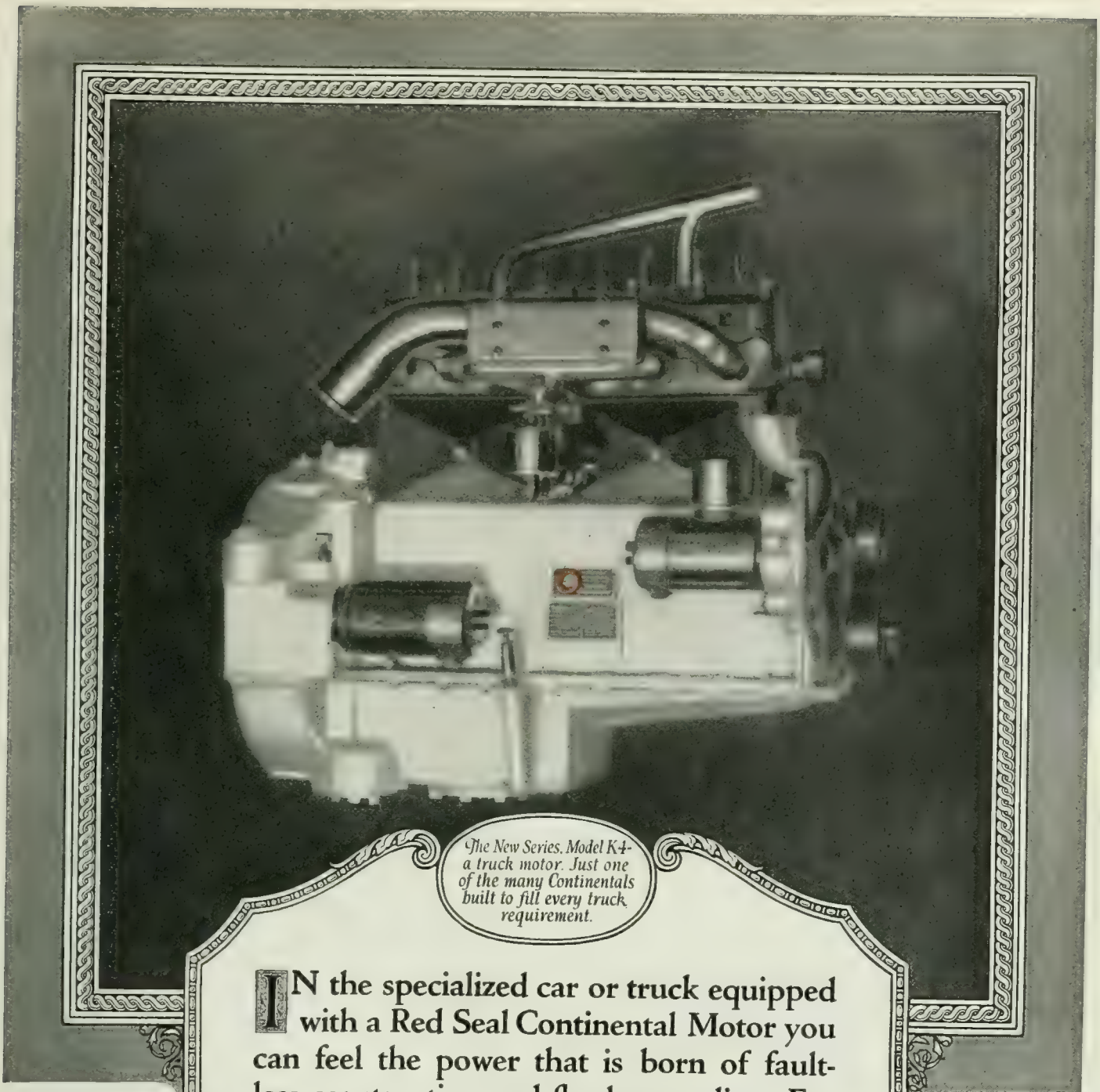
ALUMINUM BRONZE AS AN ENGINEERING MATERIAL. By W. M. Corse. Published in *Mechanical Engineering*, May, 1923, p. 283; 5 figures.

ALUMINUM BRONZE AS AN ENGINEERING MATERIAL. Published in *Chemical and Metallurgical Engineering*, May 14, 1923, p. 863.

THE ENGINEERING INDEX FOR 1922. Published annually by the American Society of Mechanical Engineers, New York City.

Some 1300 periodicals, reports and other publications regularly received during the year by the Engineering Societies' Library have been reviewed and from over 600 of these the articles to be indexed have been selected. The items are unusually concise and the number is considerably larger than heretofore. Frequent users of the index will find that the classification and the system of cross-indexing have been improved. The extended list of references to bibliographies is an instance of the attention that has been given to details.

(*Concluded on p.* 16)



The New Series, Model K-4— a truck motor. Just one of the many Continentals built to fill every truck requirement.

IN the specialized car or truck equipped with a Red Seal Continental Motor you can feel the power that is born of faultless construction and flawless quality. For twenty-two years such perfection has been represented by—the Continental Red Seal.

Built by the largest motor Specialists in the world

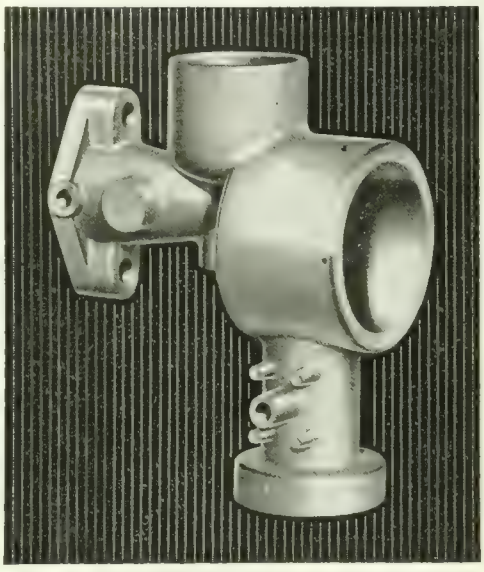
CONTINENTAL MOTORS CORPORATION
Detroit and Muskegon, Michigan

CONTINENTAL MOTORS
Powerful as the Nation
AMERICA'S STANDARD

DOEHLER

The World's Largest Producer of

DIE-CASTINGS



Doehler Die-Cast Aluminum Carburetor Connection

Where die-castings are to be plated, enamelled, or given other special finish, Doehler engineers are ready with chemical and metallurgical experience invaluable to a customer because of its unequalled scope and diversity.

To produce die-castings that are right is but part of the Doehler policy.

The Doehler Company feels equally obligated to give to its customers every assistance in using those die-castings to best advantage, that the utmost on the investment may be realized.

DOEHLER DIE-CASTING CO.
BROOKLYN. N.Y.
TOLEDO. OHIO.

NOTES AND REVIEWS

Concluded

BIBLIOGRAPHY OF AERONAUTICS. 1917-1919. Compiled for the National Advisory Committee for Aeronautics by Paul Brockett. Published by the Government Printing Office, City of Washington.

This work covers the literature published from Jan. 1, 1917, to Dec. 31, 1919, and continues the work of the Smithsonian Institution issued as Vol. 55 of the Smithsonian Miscellaneous Collections, which covered the material published prior to June 30, 1909, and the work of the National Advisory Committee for Aeronautics as published in the Bibliography of Aeronautics for the years 1909 to 1916. The National Advisory Committee for Aeronautics will next present a bibliography for the years 1920 and 1921 in one volume, and it is the Committee's intention to publish a Bibliography of Aeronautics annually thereafter.

FATIGUE IN METALS. By C. F. Jenkin. Paper read before the Royal Aeronautical Society, Dec. 7, 1922. Published in *Chemical and Metallurgical Engineering*, May 7, 1923, p. 811.

The author demonstrated the theory of fatigue by the use of a model. It was found that the results predicted by the model agreed with the test data. The author proposes to use this model to form the basis of accurate strength calculations and to introduce fatigue limits into steel specifications.

AIRCRAFT DEVELOPMENT SINCE THE ARMISTICE. Part 1—Airplanes; Part 2—Armament; Part 3—Engines; Part 4—Equipment. Prepared by the engineering division of the Air Service, McCook Field, Dayton, Ohio. Published as Air Service Information Circular No. 402 by the Government Printing Office, City of Washington.

THE STEAM WAGON FROM THE DESIGNER'S POINT OF VIEW. By F. J. Bretherton. 28 pp.; 25 illustrations.

THE USE AND LIMITATIONS OF THE STEAM WAGON. By C. Le M. Gosselin. 17 pp.; 11 illustrations.

Two reprints published by the Institution of Automobile Engineers, April, 1923.

TESTING THE QUALITY OF LUBRICATING OILS. By Winslow H. Herschel. Published in the *Proceedings of the Engineers' Society of Western Pennsylvania*, January, 1923, p. 503.

VISCOSITY OF LUBRICATING OILS AT HIGH PRESSURES. Progress Report of the Special Research Committee on Lubrication of the American Society of Mechanical Engineers. Published in *Mechanical Engineering*, May, 1923, p. 315.

EXPERIMENTS WITH FABRICS FOR COVERING AIRPLANE WINGS. By A. Pröll. National Advisory Committee for Aeronautics Technical Note No. 137. 37 pp.; 33 illustrations.

THE MEASUREMENT OF AIRFLOW. By R. O. King. Published in *Engineering*, April 13 and April 20, 1923.

Discusses the measurement of airflow by a throttle plate with special reference to the measurement of the air supply to internal-combustion engines.

MONEL METAL. By John Arnott. Published in *Engineering*, April 20, 1923, p. 495.

SOME NOTES ON THE DESIGN, CONSTRUCTION AND OPERATION OF FLYING BOATS. By Major J. D. Rennie. Published in the *Journal of the Royal Aeronautical Society*, April, 1923, p. 123.

WIRELESS IGNITION. Verbatim copy of the patents taken out by Robert Bosch. Published in *La Pratique Automobile*, April 1, 1923, p. 9348.

TESTING MACHINE DEVELOPED TO SOLVE GEAR-STRENGTH PROBLEM. By Wilfred Lewis. Published in *Automotive Industries*, May 3, 1923, p. 974.

RECENT DEVELOPMENTS IN AIRCRAFT ENGINES IN THE NAVY. By Bruce G. Leighton. Published in *Aerial Age*, May, 1923, p. 220.

NEW LONG-LIFE MOLD DEVELOPMENT. By Dr. Richard Moldenke. Paper presented at the annual meeting of the American Foundrymen's Association. Published in *The Iron Age*, May 3, 1923, p. 1251.

GARDNER

The Guaranteed Car

THE faith of the Gardner Motor Company in its product speaks in the full *one-year written guarantee* accompanying every Gardner sold—a guarantee backed by an organization of 40 years standing.

Besides the Gardner, Westinghouse Starting, Lighting and Ignition Equipment is the choice of a large number of car builders who do not choose materials for their cars because of low purchase price. *Like Gardner,* their selections are guided by the reliability of the supplier and the ability of the apparatus to function properly when built into the automobile for which especially designed.

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY
Automotive Equipment Department, Sales and Service Headquarters: 82 Worthington St., Springfield, Mass.

Westinghouse

DU
WINDOW

RA

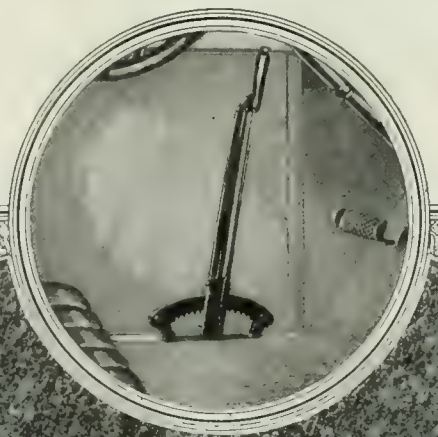
REGULATORS

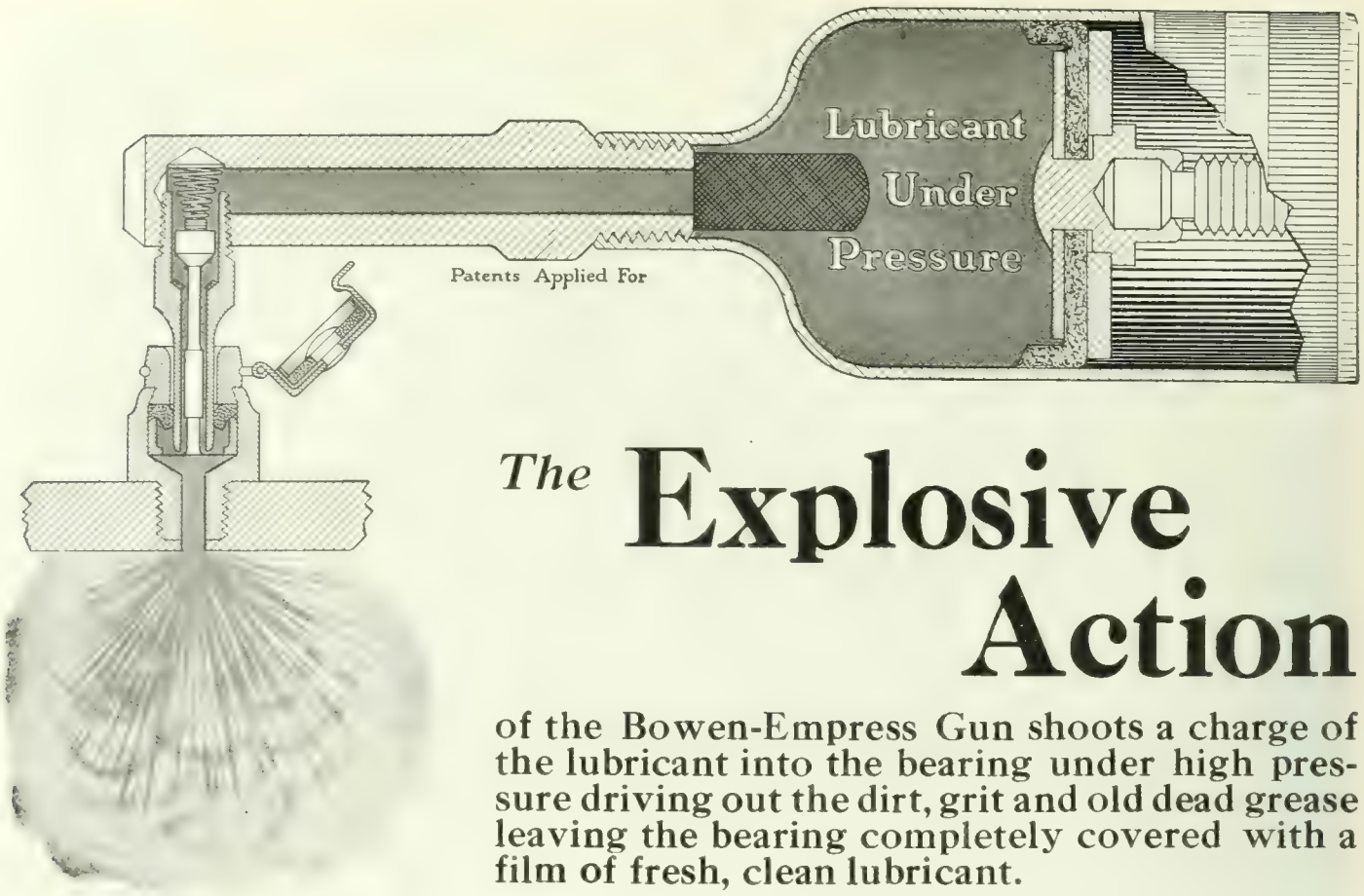
WITH one swift motion, the new lever type of Dura Window Regulator raises or lowers the glass and locks in any position as securely as the brake on your car.

Dura alone has developed the lever action window regulator, and this new regulator represents the utmost convenience which our entire experience has taught.

Installed on the face of the door instead of the pillar, the new Dura lifter has no rights or lefts. It weighs only three pounds and a quarter, including the handle. In operation it is as perfect as the motion of your arm.

The DURA COMPANY, *Toledo, Ohio*





The Explosive Action

of the Bowen-Empress Gun shoots a charge of the lubricant into the bearing under high pressure driving out the dirt, grit and old dead grease leaving the bearing completely covered with a film of fresh, clean lubricant.

Before applying the Bowen-Empress Gun to the fitting on the bearing, pressure is first developed in the gun by turning the plunger forcibly against the lubricant. A check valve in the nozzle holds the pressure within.

Next, using one hand only the connection cover is lifted with the slotted gun end and the nozzle thrust into the connection, the valve in the nozzle coming in contact with the trip in the bottom of the connection releasing the pressure and instantaneously flooding the bearing with a charge of the lubricant. The dust tight connection cover is then snapped shut using the gun end. Then withdraw the gun and develop the pressure for the next bearing.

Quick, Clean and Convenient. No connections to make between gun and fitting. No easily mislaid dust caps to remove and replace. No dirt collecting open ball check fittings. No flexible hose to break under pressure. Unnecessary to lock gun to fitting on bearing or to turn back plunger to relieve pressure before removing gun from fitting on bearing.

The Bowen-Empress System can be used with either oil or grease as the lubricant.

One Hand Operates It

Bowen Products Corporation

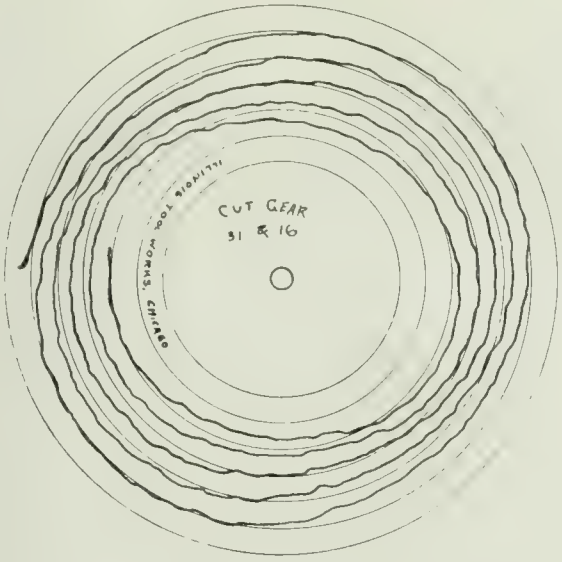
Auburn Division, Auburn, N. Y.

Write for Descriptive Booklet—No. N-301

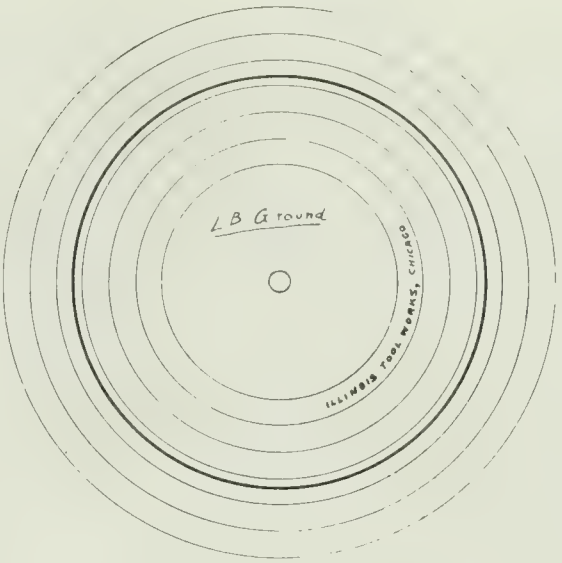
Bowen-Empress

HIGH PRESSURE LUBRICATING SYSTEM

FOR ALL MOTOR CARS AND TRUCKS



Test of Cut Gear



Test of L-B Ground Gear

Sound Waves Eliminated by Lees-Bradner Gear Grinder

The charts reproduced above were made on a velocity ratio testing machine at the Cadillac factory—waves in the line represent variations in angular velocity of the gear under test.

These waves make gear noise, cause excessive wear on gear teeth, destroy efficiency and produce destructive vibration. L-B Grinding of gear teeth corrects these errors whether caused by tooth form or spacing.

"These are the only perfect gears I ever saw," said the man who sells the velocity testing machine. They are so near to absolute perfection that we have found it necessary to construct a new type of testing machine—one which will measure a tenth of a thousandth of variation in tooth form or spacing. Ask for information about the Lees-Bradner Gear Tester.

With years of development, three years of production test in the hands of users, and ten times as many gear grinders in daily service as have been shipped by all competitors combined, we are offering a practical production machine. The Lees-Bradner Gear Grinder is protected by broad patents and users are protected by our long experience.

The LEES-BRADNER CO., Cleveland, Ohio, U. S. A.

A good bearing
It is not difficult to make a ball bearing. But a good bearing is a distinct achievement. The Schatz Universal Annular Ball Bearing embodies exclusive features of design and the highest manufacturing practice.
Specify the bearing with a margin of safety—Schatz Universal.
The Federal Bearings Co., Inc.
Poughkeepsie, N. Y.
Schatz
"UNIVERSAL"
Registered
BALL BEARING

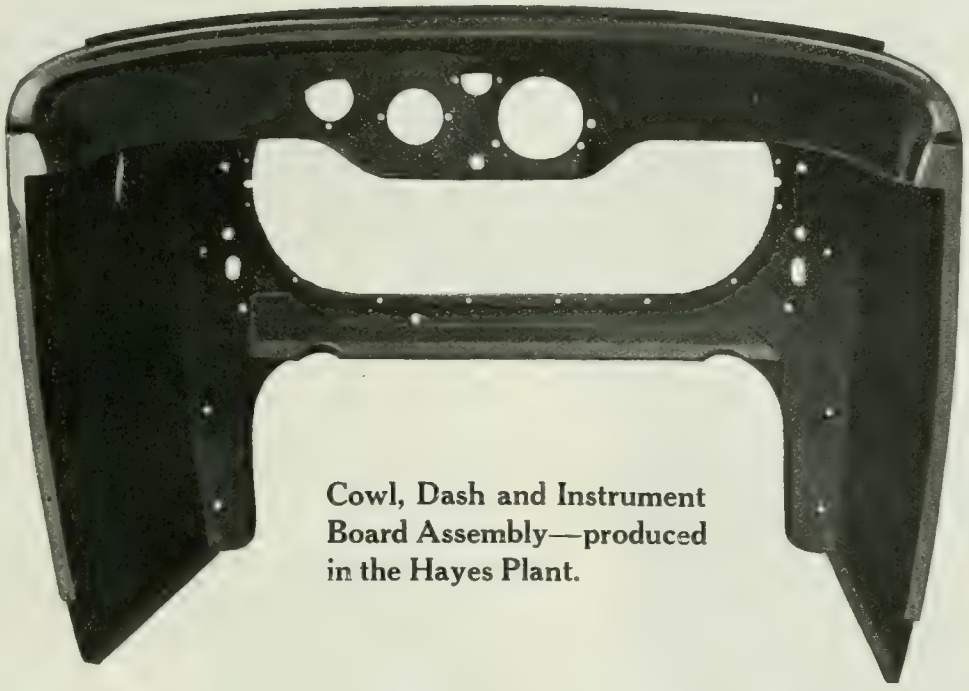
You See

Every Day

HAYES MFG. CO.
HAYES
DETROIT, MICH.

Every-where

Sheet Metal Products



Cowl, Dash and Instrument Board Assembly—produced in the Hayes Plant.

HAYES Manufacturing Company specializes in the production of Automobile Body Stampings.

Its whole equipment is planned for the rapid, economical production of automobile body parts that, because of their accuracy, lend themselves to rapid, uninterrupted assembly.

Hayes designs and builds its own dies—and the Company has a reputation for meeting specifications to a nicety.

Send us your blue prints for Body Stampings, Fenders, Hoods and other Standard or Special Sheet Metal Parts. Estimates furnished promptly.

Hayes Manufacturing Company

DETROIT, MICH.

An Important Factor in Automobile Value

FIRESTONE Gum-Dipped Cords add to the value—the appearance, the economy and the life—of any car.

Carefully developed over a period of 22 years, Firestone quality is today at the peak.

Many special manufacturing processes have been worked out and perfected in the betterment of Firestone Cords.

Gum-Dipping, air-bag cure, rubber blending and tempering, as Firestone employs these processes, result in stronger, yet more resilient tires of much longer mileage.

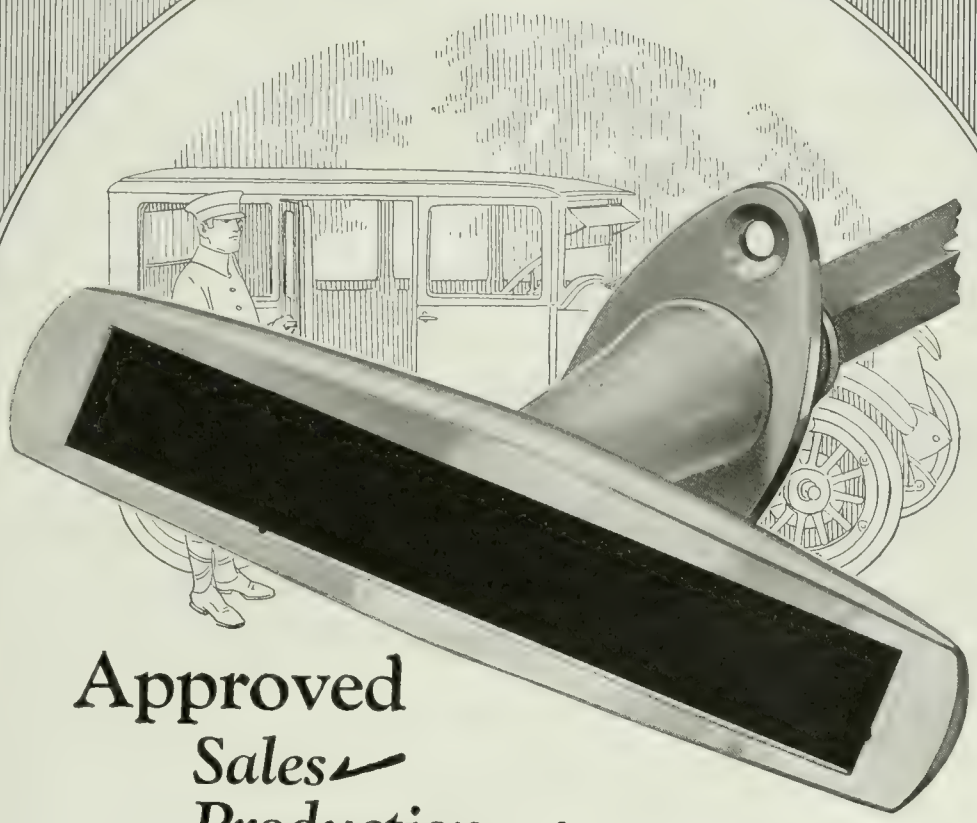
The true importance of these factory methods lies in the uniformity they insure. High quality in Firestone Cords is unvarying in hundreds of thousands of tires.

Most Miles per Dollar

The Mark of Quality

Firestone

BASCo



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Sales
Production
Purchasing

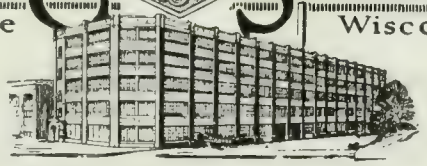
THE stamp of approval! Years of serving the automotive industry have placed Basco body hardware and electrical components on *the majority* of American cars and trucks. A splendid tribute to twelve years of service.

We are proud of it. We believe it proves that Briggs and Stratton have the comprehension and vision to grasp the desires of engineering, production and purchasing departments, and fuse them into a finished product! Briggs and Stratton does that for other leaders of the industry—and can do it for you.

Lighting, Ignition and Starting Switches, Instrument Panels, Generator Cutouts, Horns, Body Hardware including Locking and Non-Locking Outside Handles, Inside Levers and Knobs, Door Locks and Hinges, Tool Box, Pillar, Deck and Compartment Locks. The new Basco catalog is ready for mailing to Automobile, Truck and Body Builders.

Briggs & Stratton Co.
Milwaukee Wisconsin

BASCo



Thoroughbred

NEVERLEEK adds the touch of elegance that distinguishes fine cars. It marks the thoroughbred. For years it has been the standard top material of the leading automobile manufacturers and custom-body builders. Each year brings increased recognition of its pre-eminence.

Its beautiful surface reveals style and smartness; rugged endurance is built into the texture. Neverleek holds its cut and fit throughout the life of the car, and maintains its original lustre and trimness under severest conditions. Blistering sun cannot fade it or crack it. Heavy wet snow cannot make it sag or stretch.

Neverleek samples in different grains and with many styles of linings, with prices, will be sent to automobile manufacturers and top and body makers upon request.

NEVERLEEK
TOP MATERIAL
Trade Mark Reg. U. S. Pat. Off.

F. S. CARR COMPANY, 31 Beach Street, Boston, Mass. *Branch Offices*, Detroit, St. Louis, Atlanta

Bronze Piston Rings Greatly Reduce Cylinder Wear and Piston-Groove Wear and Reduce Ring Friction to a Minimum

AN ANNOUNCEMENT TO AUTOMOTIVE ENGINEERS

BY THE REUS MANUFACTURING CO., BALTIMORE, MD.

EXPERIMENTS that have been made by Automotive Engineers with unusual frequency since the earliest days of the automobile industry, covering many changes in the proportion and design, indicate the importance attached to piston rings.

To attempt to enumerate the changes that have been made in piston rings would be impossible because many which never extended beyond the experimental stage have been lost sight of; while of those that have remained, few represent marked progress.

Piston rings are vital to motor efficiency. The functions of piston rings are many-fold. Upon piston rings depend the power generated by the motor, the economy of that power, effective combustion and life of the motor.

Since practically every part of the motor is a working part, being in constant motion and usually under high speed conditions, the profession has solved most of the problems associated therewith by selecting special metal in the various phases of manufacture.

This is illustrated in the case of wrist pin bushings, crankshaft bearings, valves, cylinders, gears, etc. Bearings, for instance, are made of the highest grade of bronze in order to overcome the friction and heat which produce wear. Valves are also made of special metal which withstands extreme heat without warping; while with pistons, gears and other working parts, metal insuring utmost efficiency likewise is used.

Adhering to this fundamental principle, the Reus Manufacturing Company, after several years of experiment in the making of piston rings, has perfected the REBCO BRONZE PISTON RING. Early in these experiments we recognized that bronze was the only metal that would meet the requirements, therefore our efforts were concentrated upon a method of manufacture that would enable us to produce an efficient bronze ring at a price warranting competition with commonplace cast iron rings.

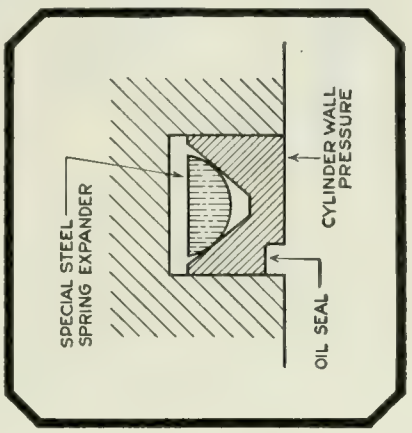
That our efforts have been successful is proved by the tests made under actual driving conditions and under most exacting circumstances. Further evidence of our successful achievement is contained in a statement made by a technical demonstrator of a well-known automobile at the recent New York Show, who in reply to a question as to the reason why the particular motor used only two rings instead of three rings on each piston, replied:

"One of the reasons why we made that change was to reduce friction on the cylinder walls, as the great amount of friction and wear created by the rings in a motor is being realized more and more. A BRONZE PISTON RING is on exhibition in this building for the first time, which to my mind seems to be a great step forward in reducing the friction and wear on the cylinder walls."

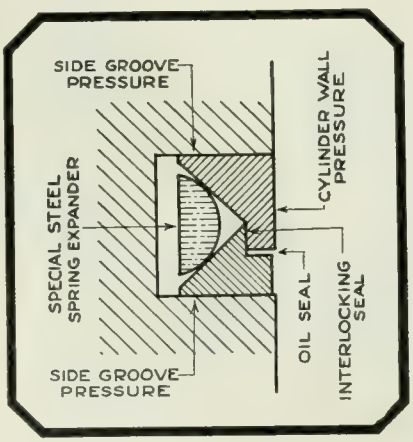
Tests which have been made prove that REBCO BRONZE PISTON RINGS in reducing the wear in a motor, naturally enhance the general efficiency and prolong the life of the most vital parts of a motor.

After very extensive road tests with REBCO BRONZE PISTON RINGS in a motor with 3¾-inch bore, the rings being ¼ inch in width, we found the following results: The motor being new, it was equipped with a complete set of twelve (12) BRONZE rings. After 3800 miles two of the rings were removed, the cylinders were accurately gauged and showed less than .0005-inch wear and the rings showed only the usual wear required to properly seat them.

The second inspection was made after the car had gone 7800 miles, when two more rings were removed and showed several thousandths of an inch wear; and when gauging the cylinders, we found them to show practically no wear beyond that shown on the first inspection. The third inspection was made after the car had been run 11,000 miles and results were practically the same.



Rebco Single



Rebco Dual

The final inspection was made after car had gone 19,800 miles and the cylinders were found to have about .001-inch wear and the grooves of the pistons were practically perfect. While the BRONZE rings showed more face wear than the conventional type, cast iron rings, the bronze rings were still good and in serviceable condition.

Admitting that a BRONZE ring will wear slightly more than a cast iron ring, nevertheless in the interest of motor efficiency it is easier and much cheaper to renew rings than to regrind cylinders, which also requires a complete set of oversize pistons and rings and considerable delay.

Another factor in favor of bronze as the ideal piston ring metal is that bronze, being a natural conductor of heat, passes heat off quickly.

The frictional resistance of REBCO BRONZE PISTON RINGS is considerably less than that of cast iron rings of the same width; and for this reason a wider ring may be used to distinct advantage, which also prolongs the life of the ring.

The spring tension of REBCO BRONZE PISTON RINGS is provided by means of a steel expander. The steel expander is made of chrome-vanadium nickel steel and will withstand any temperature in a motor under working conditions without the slightest possibility of losing any of its spring tension. The steel expander in the DUAL ring keeps the bronze members properly adjusted to the cylinder wall and both sides of the piston groove, thereby overcoming any possibility of the passing of oil. The steel expander in the SINGLE ring makes it function the same as any one-piece, conventional type, cast iron ring.

REBCO BRONZE PISTON RINGS have a low wall tension but are so designed that the tension can be increased or decreased to meet any special requirement, thus giving perfect control of wall tension.

In order that REBCO rings may be tried under every condition of motor performance, we will forward a set or sets to Automotive Engineers for their inspection and testing.

The features of REBCO BRONZE PISTON RINGS are PERFECT SERVICE—REASONABLE COST—and PROLONGED LIFE OF THE CYLINDER WALLS AND PISTON GROOVES.

ATWATER KENT

MAKERS OF

The World's Highest Grade Ignition, Starting and Lighting

ATWATER KENT Ignition, Starting and Lighting Systems are carefully designed and built to secure maximum performance under all conditions of operation or climate.

The units are compact, highly efficient and sturdy.

They will improve the performance of any motor and give long and satisfactory service.

ATWATER KENT MANUFACTURING COMPANY, PHILADELPHIA, PA.

4953 STENTON AVENUE

"33.8 Miles to the Gallon"

is the A. A. A. Coast to Coast record made by the "Gray"—it has Westinghouse ignition and Bakelite insulation.

Westinghouse

Gray

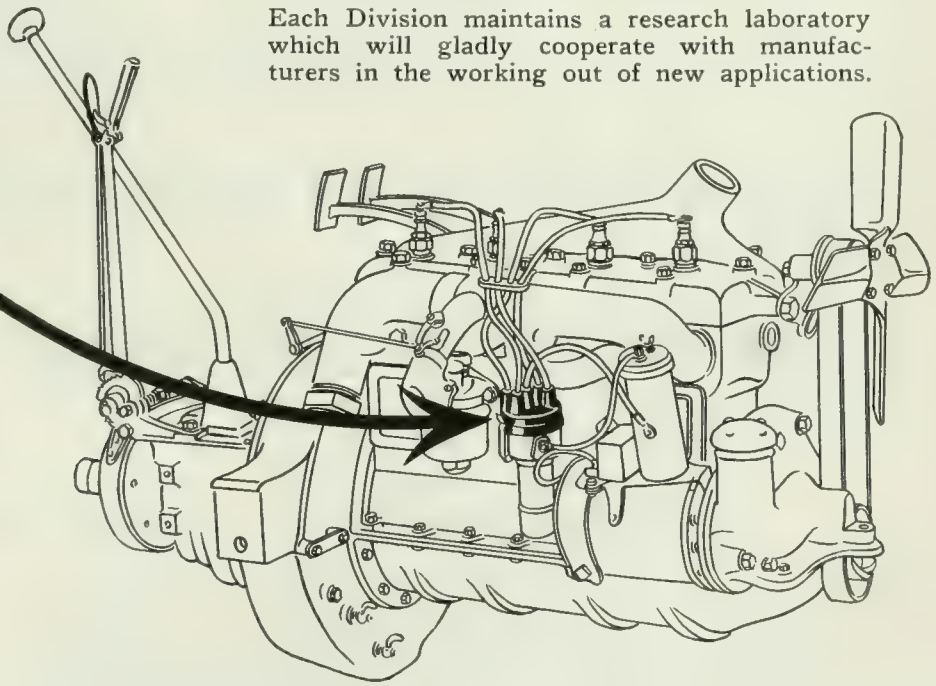
ONLY a molded insulation possessing a rare combination of essential properties may successfully be used for ignition distributor caps. Being set close to the motor it must resist high temperatures. It is essential that it be immune to injury from severe vibration and impervious to oil and moisture.

Since it meets all these requirements and is also noted for its high dielectric strength, molded phenol resin has become the universally accepted standard for ignition insulation. It is known by the trade-marks Bakelite—Condensite—Redmanol.

BAKELITE CORPORATION

Address the Divisions

Each Division maintains a research laboratory which will gladly cooperate with manufacturers in the working out of new applications.



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The Material of a Thousand Uses

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The New York Office is just as anxious as the individual members that they receive THE JOURNAL and other communications promptly.

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Members notify the office whenever they make a change in their business connection or their mail address or both.

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Your cooperation is necessary and will be greatly appreciated.

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OF

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PRICE TO MEMBERS $2.00 PER PART

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PRICE TO NON-MEMBERS $10.00 PER PART

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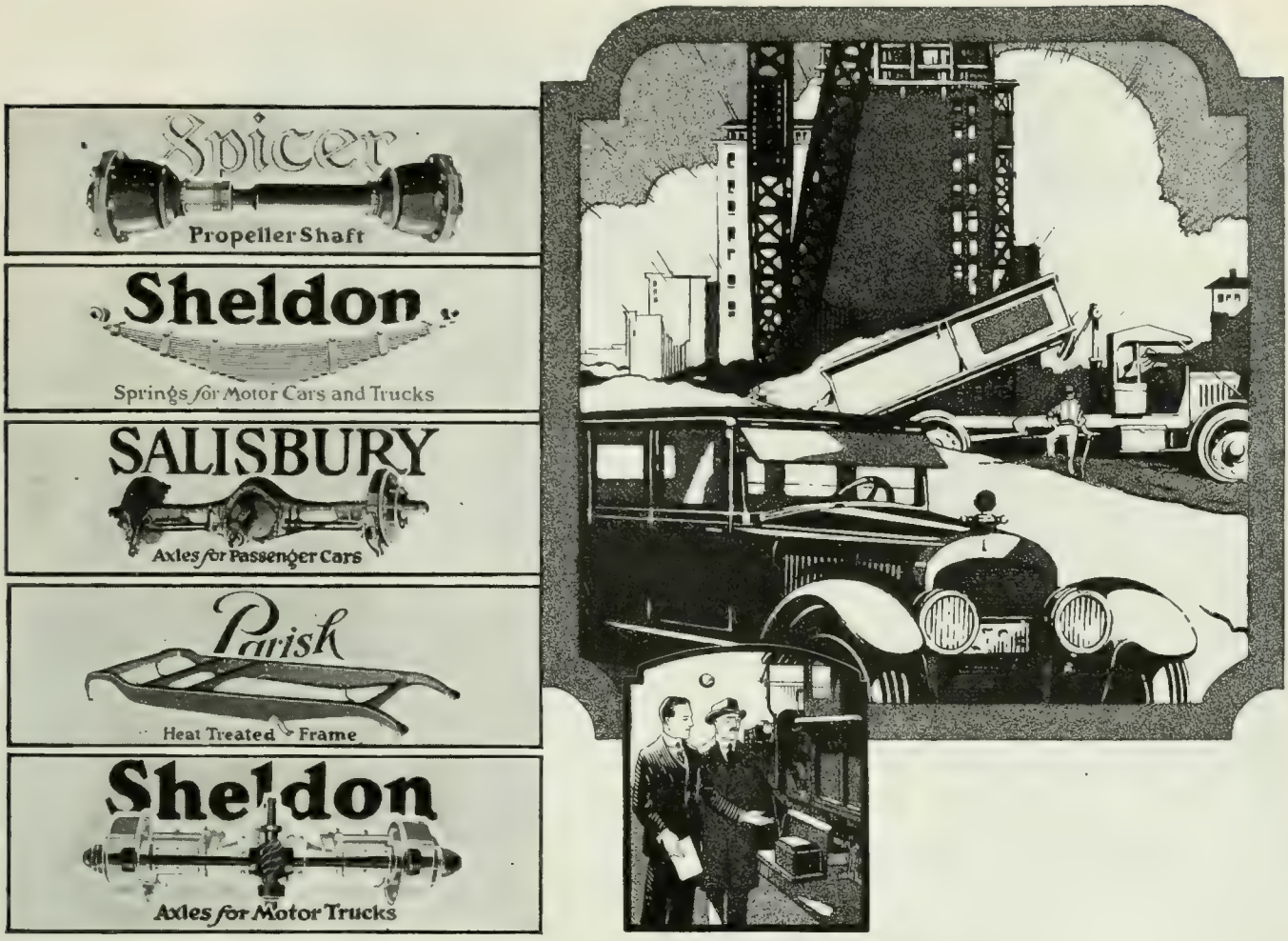

Known Quantities

GREATER to-day than ever is the public's tendency to select its motor cars and trucks on the basis of *known quantities* —units which are the product of specialized engineering; units whose reputations are established; units whose performances have had the infallible test of time.

Load-carrying and power-transmitting parts like Spicer, Sheldon, Salisbury and Parish make choosing easy.

Parish Mfg. Corp., Reading, Pa., and Detroit, Mich.
Sheldon Axle and Spring Co., Wilkes-Barre, Pa.
Salisbury Axle Company, Jamestown, N. Y.
Spicer Mfg. Corporation, South Plainfield, N. J.

C. A. DANA, *President*

As smoothly as grandmother wound a bobbin of thread

THERE is really no reason why your coils should not be wound as easily and smoothly as grandmother wound a bobbin of thread.

Simply see that your next specifications call for Acme Wire—*it goes in the space.*

Acme Wire is made by a company that for years has specialized in the endeavor to make a better wire for a particular purpose. In our own plant we wind hundreds of thousands of coils, and so know exactly what magnet wire should be and what it should do.

The difference between Acme Wire and other magnet wire is only a matter of degree. Probably with the naked eye you could not detect this difference. Yet the fact remains that in many instances Acme Wire has reduced winding costs as much as ten to twenty per cent.

Acme Wire is uniform and free from lumps and imperfections. It insures better-wound coils and fewer rejections. A coil wound with Acme Wire will take the specific number of turns without piling up.

Throughout the entire process of making Acme Wire it is inspected to see that it is up to the high Acme standard. The result is a quality product, one that we are proud to make and you will be glad to use.

Illustrated Catalog on Request to Engineers, Purchasing Agents, Executives and Operators.

THE ACME WIRE CO., New Haven, Conn.

NEW YORK CHICAGO CLEVELAND

Some Users of Acme Magnet Wire

Atwater Kent Mfg. Co.
Azor Motor Mfg. Co.
Century Electric Co.
Dayton Engineering Laboratories Co.
Delco-Light Co.
Diehl Mfg. Co.
Domestic Electric Co.
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"Enamelite," plain enameled Magnet Wire; "Cottonite," Cotton-covered Enamelite; "Silkenite," Silk-covered Enamelite; Single and Double Cotton Magnet Wire; Single and Double Silk Magnet Wire. We also have a complete organization for the winding of coils in large production quantities.

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Flexible Varnished Tubing in all standard sizes and colors.

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Audio Transformer windings.
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Enameled wire—especially the finest sizes, 40-44 B & S gauge.
Silk and cotton-covered magnet wire.
Enameled Aerial wire—single wire and stranded.

Acme Wire

"*It goes in the space*"

The rat-tat-tat of automatic hammers on the new skyscraper—the shrill whistle of the traffic policeman—the grating and grinding of street cars—the labored rumbling of heavily laden trucks—the harsh call of the newsboy breaking through the babel of voices—all the thousand and one street noises rise in a confused roar.

Power—

Klaxon's sound is not merely loud—it is penetrating! Its unmistakable 'saw-tooth' note is distinctly heard above the roar of downtown noises. No matter what other distracting sounds may fill the air—Klaxon's distinctive note is instantly heard and as quickly regarded.

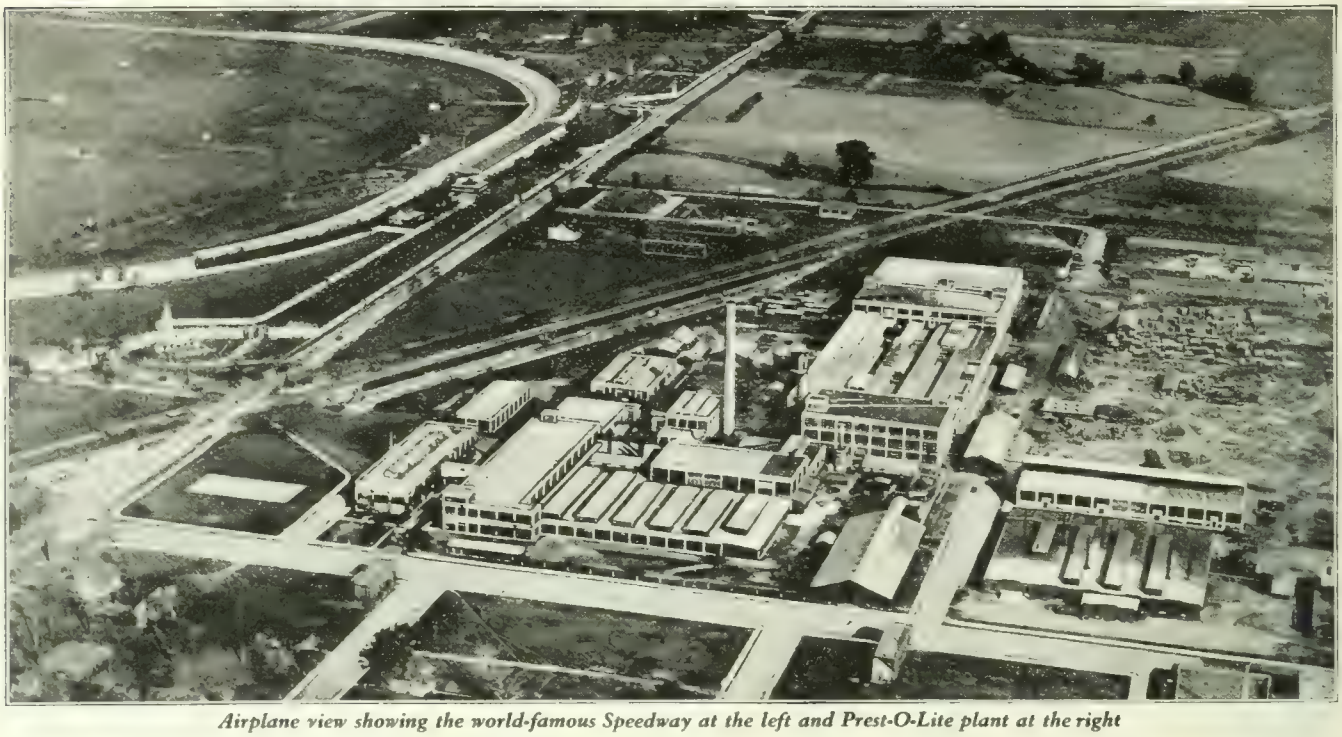
A Good Horn is Safety Insurance
Only Klaxon Quality is Good Enough

Genuine KLAXON Horns made only by

KLAXON

Company :: Newark, N. J.

Prest-



Airplane view showing the world-famous Speedway at the left and Prest-O-Lite plant at the right

The Speedway and Prest-O-Lite were built to better motoring

The same spirit which created Prest-O-Lite built the Speedway. The same organization made both—and each has been and is a direct contribution to the advancement of motoring. Because of the information gained in the great racing events on the Speedway, developments of tremendous importance in motors, tires, chassis construction and other features of the automobile have come about.

The huge Prest-O-Lite factory, just across the road from the Speedway, typifies the same devotion to advancement. Three times in eight years the plant has been greatly enlarged, to keep pace with the demands made upon it. Representing *"the oldest service to motorists,"* the plant itself symbolizes an organization that puts its full resources back of every Prest-O-Lite product and every Prest-O-Lite Service Station.

THE PREST-O-LITE COMPANY, Inc. *Indianapolis, Indiana*

New York Office: 30 East 42nd St. Pacific Coast Office: 599 Eighth St., San Francisco
In Canada: Prest-O-Lite Company of Canada, Ltd., Toronto

O-Lite

—the battery for cars

The Prest-O-Lite Battery lives up to the expectations aroused by the prominence of the plant. The constant care in selection of materials, rigid inspections and keen judgment of experts combine to present in Prest-O-Lite Batteries the power which distinguishes them, the reserve strength for emergencies and the long life and depend ability which make them excel for all-around, all-weather service.

—the gas for trucks

Prest-O-Lite Gas has always been the superior lighting equipment for trucks. With it, too, the service idea is fully carried out—as 22,000 Prest-O-Lite Gas Stations all over the country quickly exchange full tanks for empty ones, and you pay only for the gas. The equipment is approved by public authorities everywhere. It cannot be jarred, jolted or bumped out of commission, and it is as economical as it is completely satisfactory.

THE PREST-O-LITE COMPANY, Inc., *Indianapolis, Ind.*
Small Tank Sales Department

New York Office: 30 East 42nd St. Pacific Coast Office: 599 Eighth St., San Francisco
In Canada: Prest-O-Lite Company of Canada, Ltd., Toronto

THE GROWING IMPORTANCE OF *Lubrication* IN THE PUBLIC MIND

From practically every state we are getting constant reports of a rather startling increase of public interest in the question of lubrication.

The news of the remarkable savings made in repair costs by fleet owners through the methodical use of ALEMITE is spreading rapidly to the passenger car owner.

From a handy-man's job, lubrication has grown to be the biggest source of side-revenue for hundreds of garages and service stations. In one small town last year one dealer made $5,000 lubricating cars with ALEMITE. He has over 300 customers who have subscribed to a regular monthly lubricating service.

Car dealers, too, report this year, that in discussing upkeep costs an unusual proportion of purchases have hinged upon lubrication equipment—especially where the prospect is buying his second or third car.

THE BASSICK MANUFACTURING COMPANY
2654 N. Crawford Ave., Chicago, Ill.
Canadian Factory: Alemite Products Company of Canada, Ltd., Belleville, Ontario

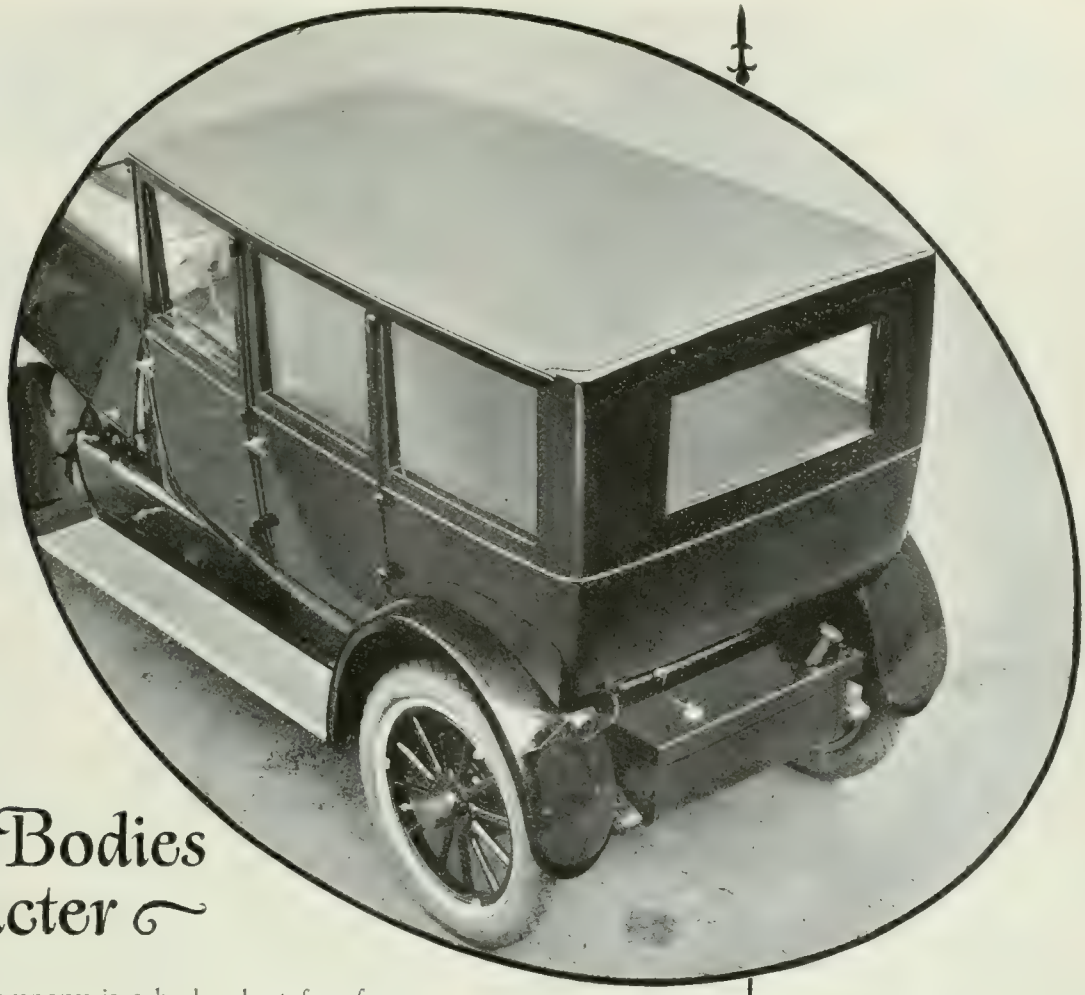
ALEMITE

High Pressure Lubricating System

Oil or Grease

The ALEMITE HIGH-PRESSURE LUBRICATING SYSTEM can be used with either oil or grease. But we recommend ALEMITE LUBRICANT, because it is a solidified oil which we have perfected especially for our System. It has all the benefits of oil, but at the same time is sufficiently solid to "stay put."

A Bassick
Alemite
Product



Raulang Bodies of Character

The Baker R & L Company is a body plant free from affiliations specializing in the making of closed bodies exclusively for the trade. This concentration of manufacture has resulted in a standard quality of workmanship at a medium price that was found heretofore only in higher priced bodies.

Our ample financing and stability insure our faithful performance of any contract; and our quantity production facilities, at least a thousand bodies per month, enable us to effect manufacturing economies that are reflected in our notably moderate prices. As a result, RAULANG Closed Bodies are found on many medium priced cars.

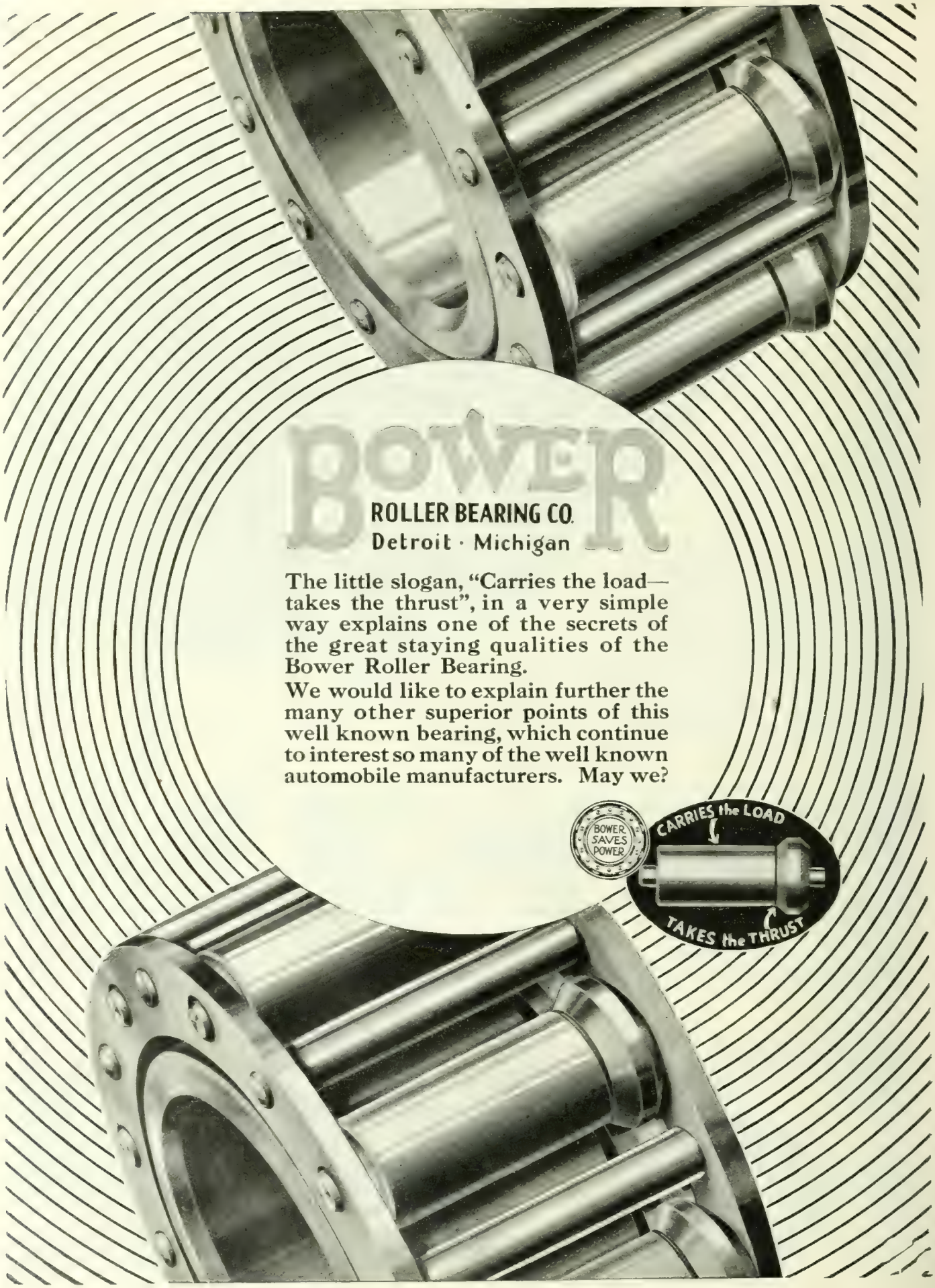
A RAULANG Body helps sell the car, because the salesman can point out those frequently unseen values of reserve strength and endurance that add to the comfort and to the silent operation of the car—not to mention the greater resale value.

Car Manufacturers

Let us do some "close figuring" on your closed body requirements.

RAULANG BODY DIVISION
The Baker R & L Co.
CLEVELAND, OHIO. U.S.A.

Raulang TRADE MARK AUTOMOBILE BODIES


BOWER
ROLLER BEARING CO.
Detroit · Michigan
The little slogan, "Carries the load—takes the thrust", in a very simple way explains one of the secrets of the great staying qualities of the Bower Roller Bearing.
We would like to explain further the many other superior points of this well known bearing, which continue to interest so many of the well known automobile manufacturers. May we?
BOWER SAVES POWER
CARRIES the LOAD
TAKES the THRUST

ULTIMATE STEELS

THE MEN RESPONSIBLE FOR THE ATLAS STEEL CORPORATION

IN the Personnel of the Board of Directors of the Atlas Steel Corporation, the buyer of fine steels finds ample assurance of the integrity and responsibility for which he rightfully looks.

Among the group of executives who direct the policy and operation of the Atlas Steel Corporation will be found men who, in individual capacities, are prominently identified with the advancement and development of the American steel industry. Associated with these executives as stockholders are a number of well-known engineers, financiers and men of affairs.

BOARD OF DIRECTORS

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Treasurer and Assistant Secretary of the Corporation

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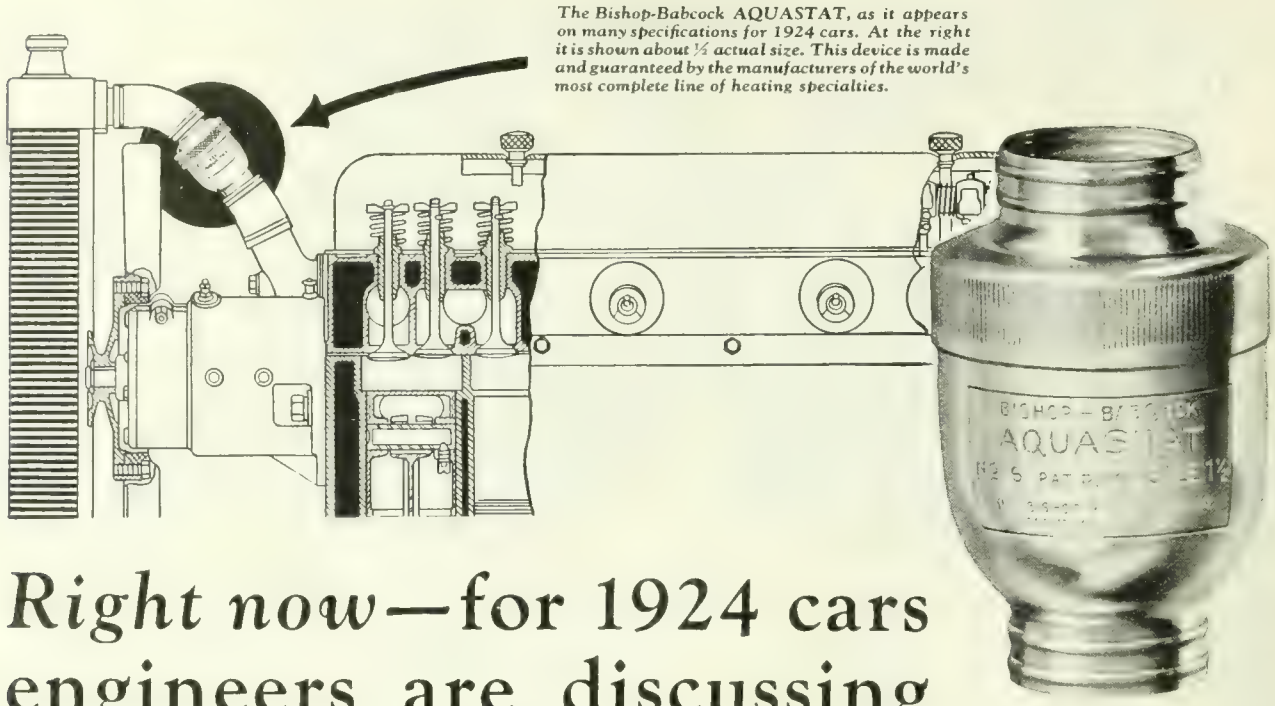
W. D. MYRES, *Secretary and Assistant Treasurer*
H. E. NICHOLS, *Treasurer and Assistant Secretary*

Highest grades of fine steels, absolute uniformity, excellence of workmanship, fair prices, and delivery promises on which the buyer can rely, constitute the basis on which Atlas solicits a trial of its products.

High Speed Steels *Carbon Tool Steels* *Alloy Tool Steels*
Automotive Steels *Die Steels* *Special Analysis Steels*
Cold Drawn Products *Carbon and High Speed Drill Rod*

THE ATLAS STEEL CORPORATION

GENERAL OFFICES, DUNKIRK, N. Y.
Plants: DUNKIRK, N. Y. CHARLEROI, PA. WELLAND, ONT.
District Sales Offices: *New York Boston Philadelphia Buffalo Pittsburgh Atlanta Indianapolis Cleveland Detroit Chicago St. Louis*
Warehouses: *Dunkirk, N. Y. Charleroi, Pa. Boston Detroit Chicago Welland, Ont.*



The Bishop-Babcock AQUASTAT, as it appears on many specifications for 1924 cars. At the right it is shown about ½ actual size. This device is made and guaranteed by the manufacturers of the world's most complete line of heating specialties.

Right now—for 1924 cars engineers are discussing the Bishop-Babcock Aquastat

The engineers are now considering various possible improvements for the new models and they must exercise a high order of technical and business judgment.

Not only must they deal with engineering factors, but in addition they must keep in mind the broader phases of their work—public opinion, dealer opinion, competition, sales and service problems, etc.

On the one hand, the engineer adds no new equipment, however meritorious it may be, until the majority of car owners and buyers are definitely conscious of the unfilled need.

On the other hand, he cannot afford to lag behind competition, handicap his sales organization and weaken the position of his dealers. Thus, his general policy must be to keep in step with the trend of the industry, neither to lead the trend nor to follow it.

Now comes temperature control

Thirty-four manufacturers are today using as standard equipment some method of temperature control.

Contacts with engineers, factory officials, distributors, dealers and an unlimited number of owners point to this conclusion: that temperature control of the cooling water is generally recognized as a necessary part of good engine design by a majority of the men interviewed.

Engineers in more than 50 important organizations are now testing the Bishop-Babcock Aquastat. Several standard equipment contracts have already been placed. Tests are progressing rapidly and have been exceedingly favorable.

Bishop-Babcock Aquastat will be standard equipment on the 1924 models of many prominent manufacturers.

What the AQUASTAT will do

The Bishop-Babcock Aquastat is guaranteed to give the following results:

(1) Adjust water temperature to seasonal conditions and prevent over-cooling.
(2) Maintain constant temperature of water around combustion chamber and cylinders.
(3) Warm up engine quickly and reduce use of choke.
(4) Save fuel and reduce carbon deposits.
(5) Minimize dilution of oil in crank case.

To check the danger of freezing, 10% seepage is allowed.

And by reason of its design, the Aquastat cannot handicap the flow of water in hot weather.

* * *

A special type of the Bishop-Babcock Aquastat for thermo-syphon cooling systems is now available. It is submitted for tests to the engineers and to the trade as the final product of exhaustive experimental work.

* * *

We invite tests from all manufacturers of automobiles and trucks, distributors and dealers, on both types of Aquastat.

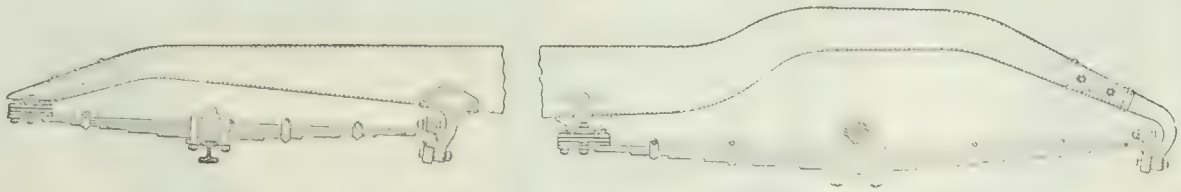
THE BISHOP & BABCOCK COMPANY
Automotive Specialties Division
CLEVELAND, OHIO

Bishop-Babcock AQUASTAT

Retail Price $10.00

Two hose sizes 1¼" and 1½"

BELFLEX FABRIC SPRING SHACKLES

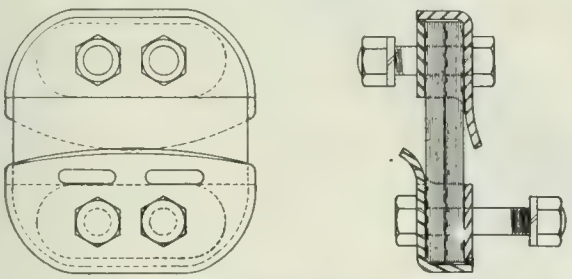


Belflex Fabric Spring Shackles applied to car with semi-elliptic springs.

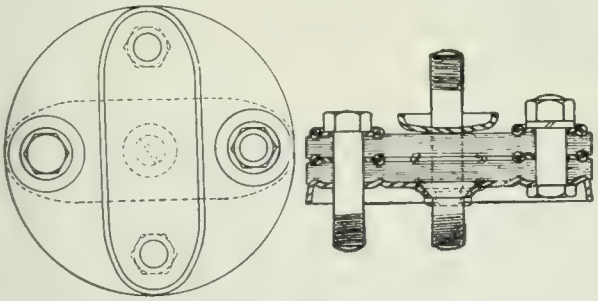
The Belflex Fabric Spring Shackle is fast becoming one of the most important completed chassis engineering developments in recent years. It is possible to use Belflex equipment on all types of spring suspension.

This fabric spring shackle achieves, without increased cost to the manufacturer, the following important advantages:

Elimination of from 12 to 16 lubricating points from the average chassis.



The Tension Shackle can be supplied in various sizes to fit any weight of car. It is the result of over three years of development work, and there is a valid reason for every detail. It is used at the rear ends of the springs.



The Pivot Shackle used at the front ends of the springs. In addition to its other advantages it takes the twisting action produced by uneven deflections away from the main leaf of the spring, giving the spring greater flexibility and increasing its life.

Substitution of noiseless fabric insulation for metallic contact between the sprung and unsprung parts of the car.

Freer action—improved riding qualities and greater life to springs.

Belflex Fabric Spring Shackles keep the car quiet without attention.

These and other important advantages of the Belflex Spring Shackle are the result of over three years of development work.

Another consideration for manufacturers and automotive engineers is the elimination of spring eyes and eye forming operations, which greatly simplifies the springs, and reduces their cost considerably.

Let us show you how Belflex equipment supersedes the old spring shackles with their squeaking and rattling bolts and bushings.

Belflex Engineers are ready to aid you in the design of equipment to conform to your chassis requirements.

Write for information today.

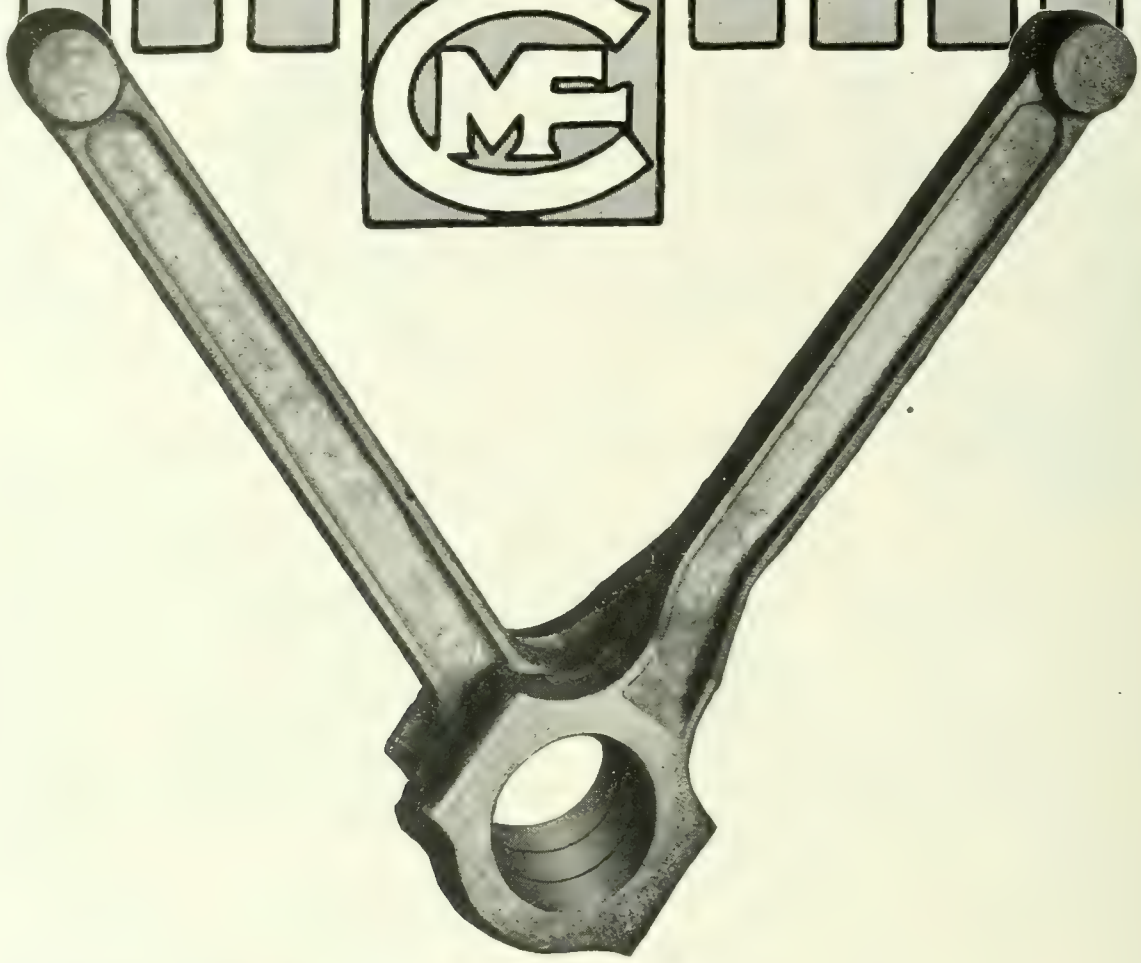
The BELFLEX Corp.

AUTOMOTIVE PRODUCTS

366 Madison Ave., New York City

Patents on Belflex Fabric Spring Shackles have been granted, and others are pending, in the U. S. and other countries

CHAMPION



The man who shops around, buying drop forgings here and there, has all the hard boiled evidence any man can desire to convince himself that all forgings are not alike and that a forging is something more than just a piece of steel formed by so many hammer blows. And that evidence is in his own office. A comparison of cost sheets showing finishing time will tell facts that no salesman dares state.

If by any chance he has bought Champion Forgings there will be unquestionable evidence that they effect true economies thru accuracy to blue print specifications, alignment and uniformity of metal. Of tool adjustments, there will be fewer; of defects causing tool breakage, there will be none. Try it out on your own cost sheets. Then send us your blue prints and specifications.

THE CHAMPION MACHINE & FORGING CO.

3695 East 78th Street **Cleveland, Ohio**

NEW YORK OFFICE—30 Church St. PHILADELPHIA OFFICE—Bourse Bldg.

DETROIT OFFICE—705 Ford Bldg.

DROP FORGINGS

That Something Else

After the manufacture itself—and before as well—there is the service-factor that completes your transactions to your pleasure or to your extreme dissatisfaction.

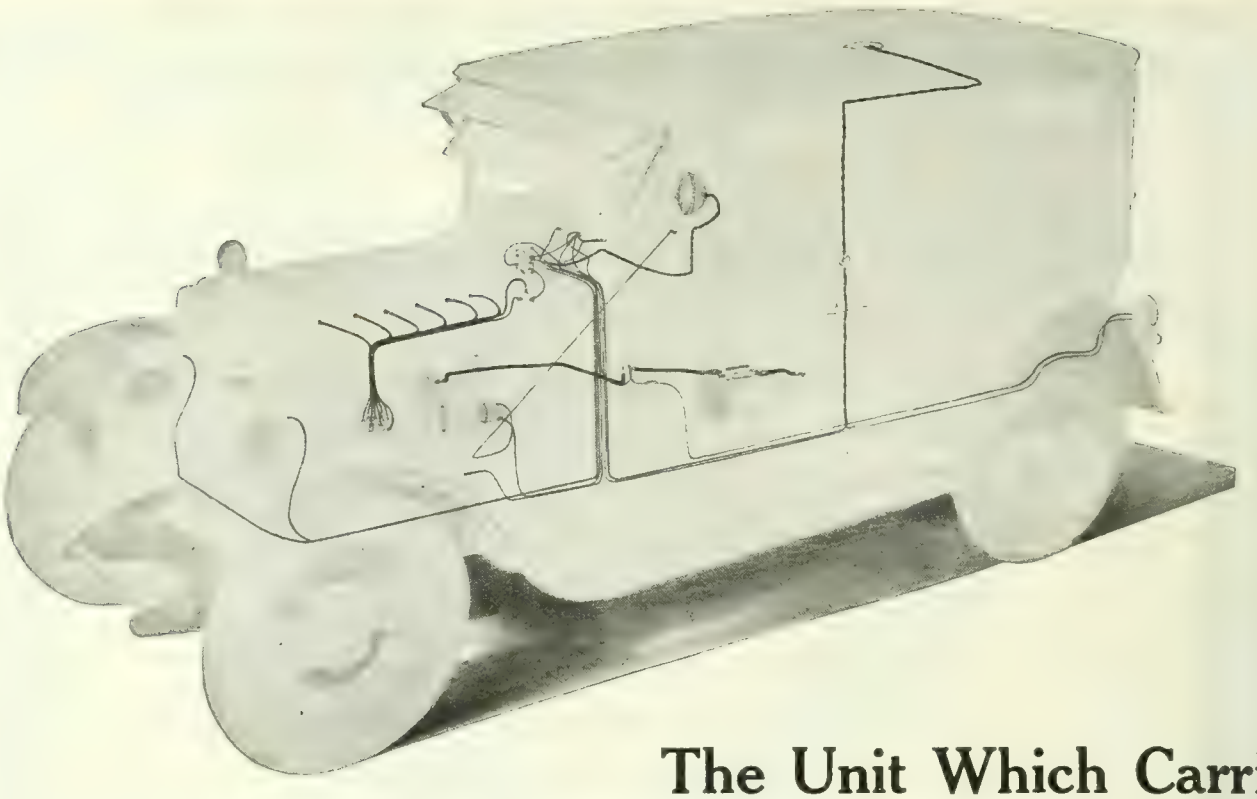
We sincerely believe you will find that the service-factor here at Interstate is very much to your liking.

We are trying consistently to make it that way—every man of us.

Open Hearth Alloy Steel Ingots, Billets, Bars
Wire Rods, Wire Nails, Rivets and Cut Tacks
Iron Bars and Railroad Tie Plates

INTERSTATE IRON & STEEL CO.
104 South Michigan Avenue
CHICAGO

Interstate Steels



The Unit Which Carries Life to the Vital Parts of Your Car

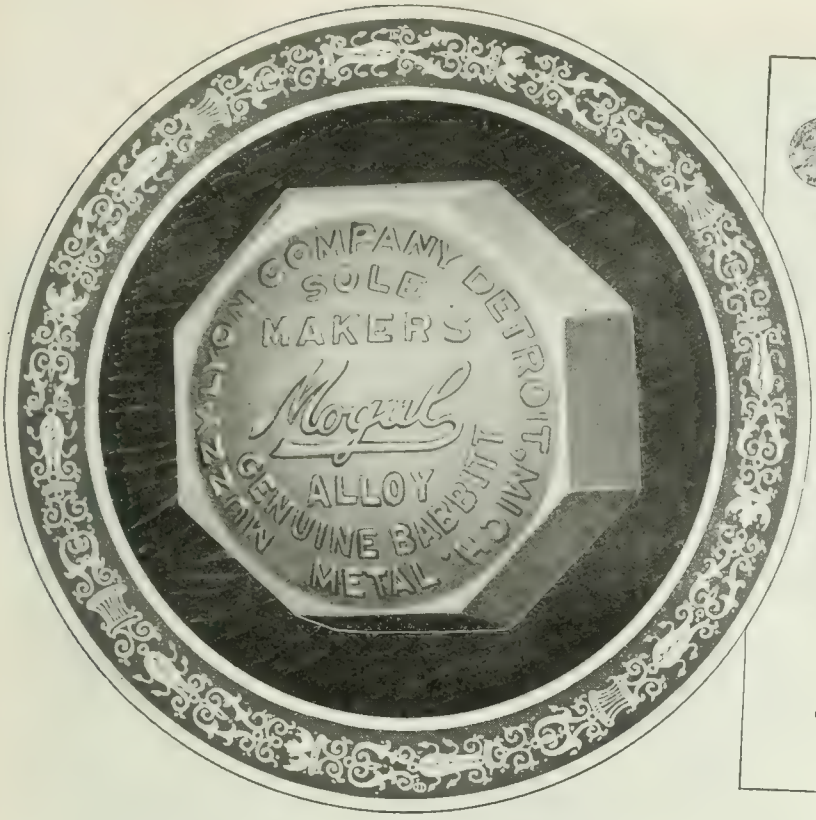
A loosened contact—a piece of insulation on the starting or ignition cable oil soaked or cracked, and the irritated motorist loses sight of the mechanical perfection of your car.

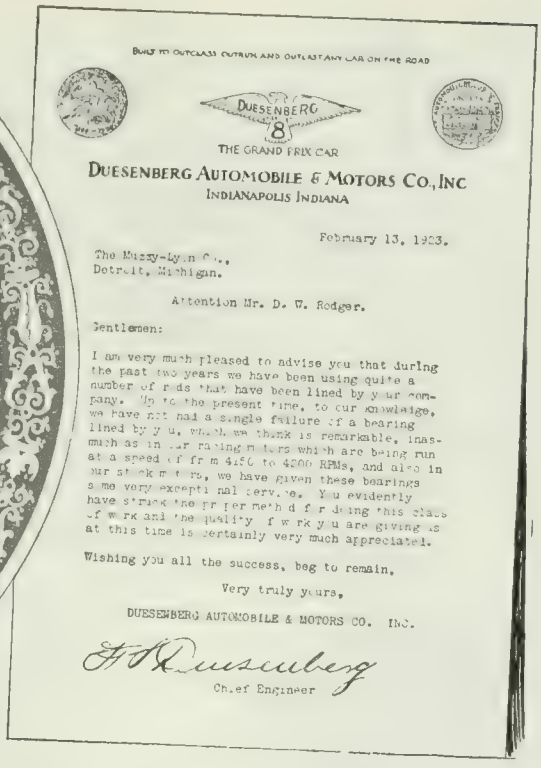
It is not for him to understand why the car won't run. His thoughts are—that long walk to the nearest telephone—that broken business engagement—and that annoying expense of receiving help from the service station.

The quality of Packard Cable is in keeping with the other vital units you have so skillfully perfected. As a unit of good repute, it affords engineering satisfaction and important sales arguments.

The Packard Electric Company

WARREN, OHIO





BUILT TO OUTCLASS OUTRUN AND OUTLAST ANY CAR ON THE ROAD

DUESENBERG 8

THE GRAND PRIX CAR

DUESENBERG AUTOMOBILE & MOTORS CO., INC
INDIANAPOLIS INDIANA

February 13, 1923.

The Muzzy-Lyon Co.,
Detroit, Michigan.

Attention Mr. D. W. Rodger.

Gentlemen:

I am very much pleased to advise you that during the past two years we have been using quite a number of rods that have been lined by your company. Up to the present time, to our knowledge, we have not had a single failure of a bearing lined by you, which we think is remarkable, inasmuch as in our racing motors which are being run at a speed of from 4150 to 4200 RPMs, and also in our stock motors, we have given these bearings some very exceptional service. You evidently have struck the proper method for doing this class of work and the quality of work you are giving us at this time is certainly very much appreciated.

Wishing you all the success, beg to remain,

Very truly yours,

DUESENBERG AUTOMOBILE & MOTORS CO. INC.

Chief Engineer

Duesenberg is a name for years intimately connected with the most searching tests of parts and materials—motor car racing.

Duesenberg has used "*Mogul Alloy Genuine*" special connecting rod metal in his motors for several years, and it has never failed him, under any condition, regardless of how severe it may have been.

No better evidence of quality could be asked for than Mr. Duesenberg's letter reproduced above.

Mogul metal fulfills every requirement of the ideal metal—pouring easily without trouble from shrinkage or blow holes, producing a bearing of very fine grain, of exceptional wearing qualities, and yielding more bearings per pound than the average bearing alloy.

MUZZY-LYON COMPANY, DETROIT, MICH.

Write for a copy of "Mogul Alloys for Better Bearings" or better still, order a trial box today.

Mogul

Engine Bearings *and* Bearing Alloys

Touring Service

Stewart
Vacuum Tank
and Speedometer

THE purchaser of a car buys transportation. But transportation is of little value unless backed up by expert service. When touring from one state to another, the car owner has a right to expect that he can obtain expert service at a point not far distant, no matter where he may be. In fact, prospective purchasers are now seriously considering the service obtainable, before they buy.

What a burden the car manufacturer must bear who is obliged to establish nation-wide service, not only for the motor and chassis, but for necessary equipment as well.

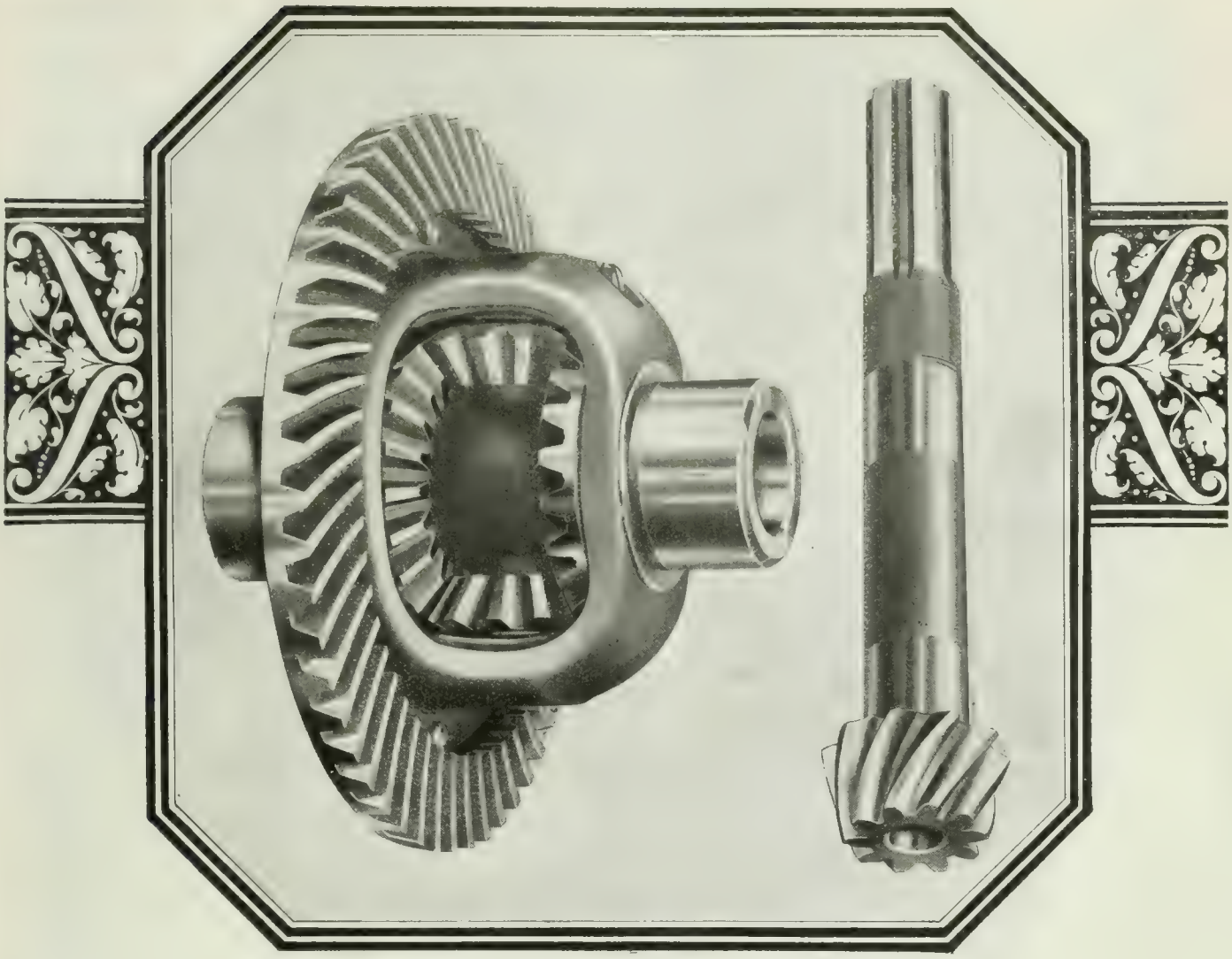
What a relief it is to the manufacturer who has Stewart-equipped his car to know that service on all Stewart equipment has been provided for in a more than satisfactory manner.

Long ago we solved this service problem with the establishment of a chain of Service Stations throughout the world, manned by experts who service Stewart equipment exclusively; fifty-four stations in the United States alone, accessibly located in the nation's largest cities.

And the remarkable fact is that although this Stewart Service system has no equal, the Stewart equipment on a car is known to require less service than any other standard equipment.

Stewart-Warner Speedometer Corporation
CHICAGO, U. S. A.

Stewart
CUSTOMBILT ACCESSORIES
USED ON 8 MILLION CARS



THE confidence which so many motor car manufacturers place in the Brown-Lipe-Chapin products is due to their record of unfailing superiority since the beginning of the industry.

Manufactured at Syracuse, N. Y.

BROWN-LIPE-CHAPIN

DIFFERENTIALS — BEVEL DRIVE GEARS

6 *Facts*

about the Dayton Dual-Pneumatic

1—Small size tires, economical and easy to handle.

2—Only one size of tire, interchangeable all around.

3—All rim clamps easily accessible, tires can be changed quickly.

4—Spoke wheel with two felloes, no pockets in which stones or dirt can lodge.

5—Decreased chassis height, making it easier for passengers to enter and leave.

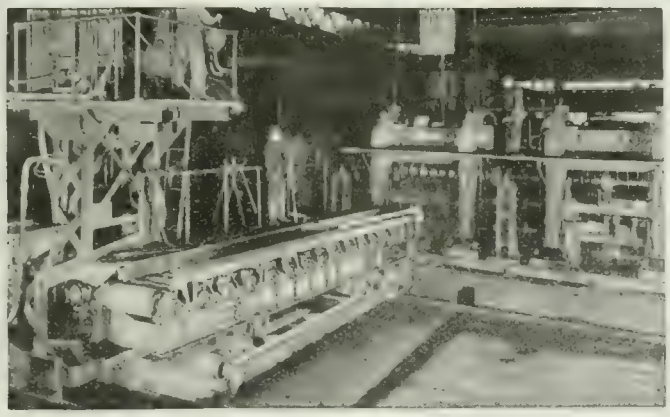
6—Dayton's unique construction, hollow spokes and rims cast in one piece of electric furnace steel; greatest strength with least weight.

It will pay you to investigate.
Write us for further information.

The Dayton Steel Foundry Co.
Dayton, Ohio

Dayton
Steel Truck Wheels
PATENTED

One of the Electric Furnaces



Part of the Timken Rolling Mill

In the Timken Tube Mill

100,000-Mile Timken TAPERED ROLLER BEARING Steel

The durability of Timken Tapered Roller Bearings is not wholly due to the fact that the steel is clean, thoroughly deoxidized, electric steel, made in the electric steel mill owned and operated by The Timken Roller Bearing Company.

Nor is Timken durability due wholly to the fact that the steel is high chromium steel which gives the rollers of anti-friction bearings the greatest possible resistance to wear and fatigue and shock.

Nor is Timken durability due wholly to the fact that in the Timken steel mill, oxidizing and reducing operations are controlled at all times during the making of the heat—a condition on which depends the successful, subsequent case-carburizing and pack-hardening of the parts of Timken Bearings—which gives them their glass-hard outer surfaces, with tough, elastic, inner cores.

Timken durability is due to the successful co-ordination of all these factors; the exacting specifications to which the special Timken electric steel is made; *and* to the high chromium content of the steel; *and* to the case-carburizing and pack-hardening of the finished parts; *and* to the accuracy of fabrication; *and* finally, to the very design of the bearing, which permits easy, quick, adjustment for the inevitable wear that *must* eventually follow motion.

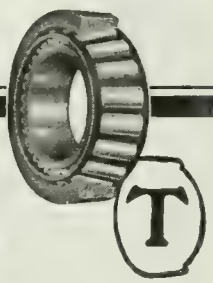
The Timken Roller Bearing Company is the only bearing company which makes its own steel and its own seamless tubes, and rods, in its own electric steel mill, rolling mill, tube and rod mill.

The Analysis of Timken Steel is:

Carbon	.15— .29
Manganese	.45— .60
Phosphorus	.04
Sulphur	.04
Silicon	.15— .20
Chromium (Cups & Cones)	.40— .50
Chromium (Rollers)	1.00—1.20

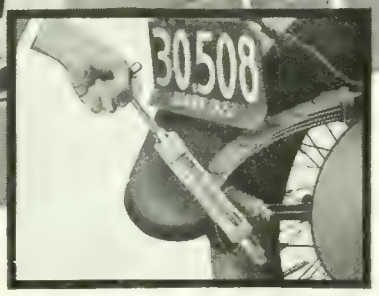
The Timken Roller Bearing Co
CANTON, OHIO

© 1923, By The T R B Co, Canton, O



TIMKEN
Tapered
ROLLER BEARINGS

3000 POUNDS



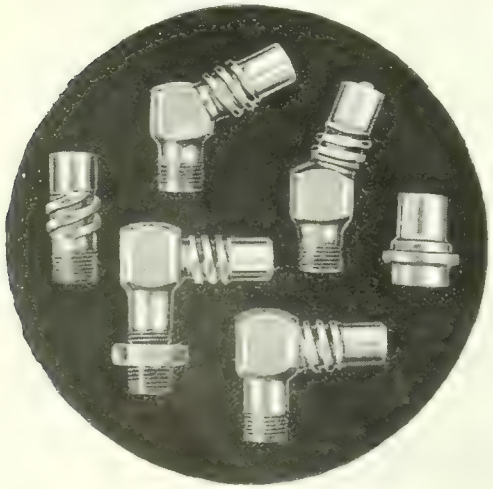
A TON and a half of pressure! That, by actual gauge test, is the pressure a man of ordinary strength can develop in the DOT, the original one-hand, direct-connection high pressure grease and oil gun.

"Three thousand pounds" is not only an argument for the power and ruggedness of the DOT, but proof of the soundness of its principle of construction.

Only through the direct, firmly supported connection of the DOT can such pressure be applied without leakage. The burly, case-hardened steel nozzle of the DOT locks *solidly* to the DOT machine-faced steel nipple. No weak connecting member—nothing to give way!

And the DOT is as handy as it is sturdy. ONE HAND is all you need for every step of the lubricating operation; one hand to connect and lock gun to nipple, one hand to develop pressure and inject lubricant, one hand to unlock and disconnect gun. No awkwardness; no messiness; no slippery coupling; no finger bruising; no pliers! Unfailing automatic valve enables use of oil as well as grease, and permits pressure to remain in the gun.

Easy access to any lubrication point on any chassis! NIPPLES for the DOT system are made in all the various forms and angles necessary for direct, one-hand connection. Nipples are steel, have ball check valve and will not leak. Slotless snap-on dust cap is of attractive design and covers valve and locking-thread completely.



FIFTY-EIGHT car and truck manufacturers have in two short years adopted the DOT as standard equipment. ONE HUNDRED leading jobbers and TWO THOUSAND dealers sell it. Send for descriptive folder.

CARR FASTENER COMPANY, Boston 39, Mass.

Makers of the "DOT" line of fasteners

Branch Offices 40 Selden Ave., Detroit
47 W. 34th St., New York

CARR FASTENER CO. OF CANADA, LIMITED
HAMILTON, ONTARIO

The DOT TRADE MARK high pressure LUBRICATOR

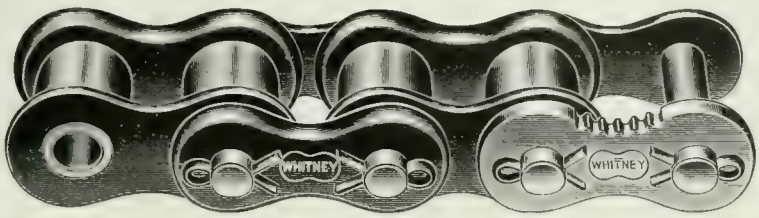
"WHITNEY"

LONG SERVICE

ROLLER CHAINS

For Motor Trucks, Tractors and Machinery

THE MOST DURABLE, Therefore
THE MOST ECONOMICAL



Cotter Detachable Type

Now that the motor truck is handling so much of the freight that was formerly cared for by the railroads, it must run on a schedule almost as exacting as that of the railroad train itself. This emphasizes the necessity of selecting a chain which can be relied on under all conditions of speed, road, and weather.

AVOID TROUBLE BY
SPECIFYING "WHITNEY"

THE WHITNEY MFG. CO., Hartford, Conn.

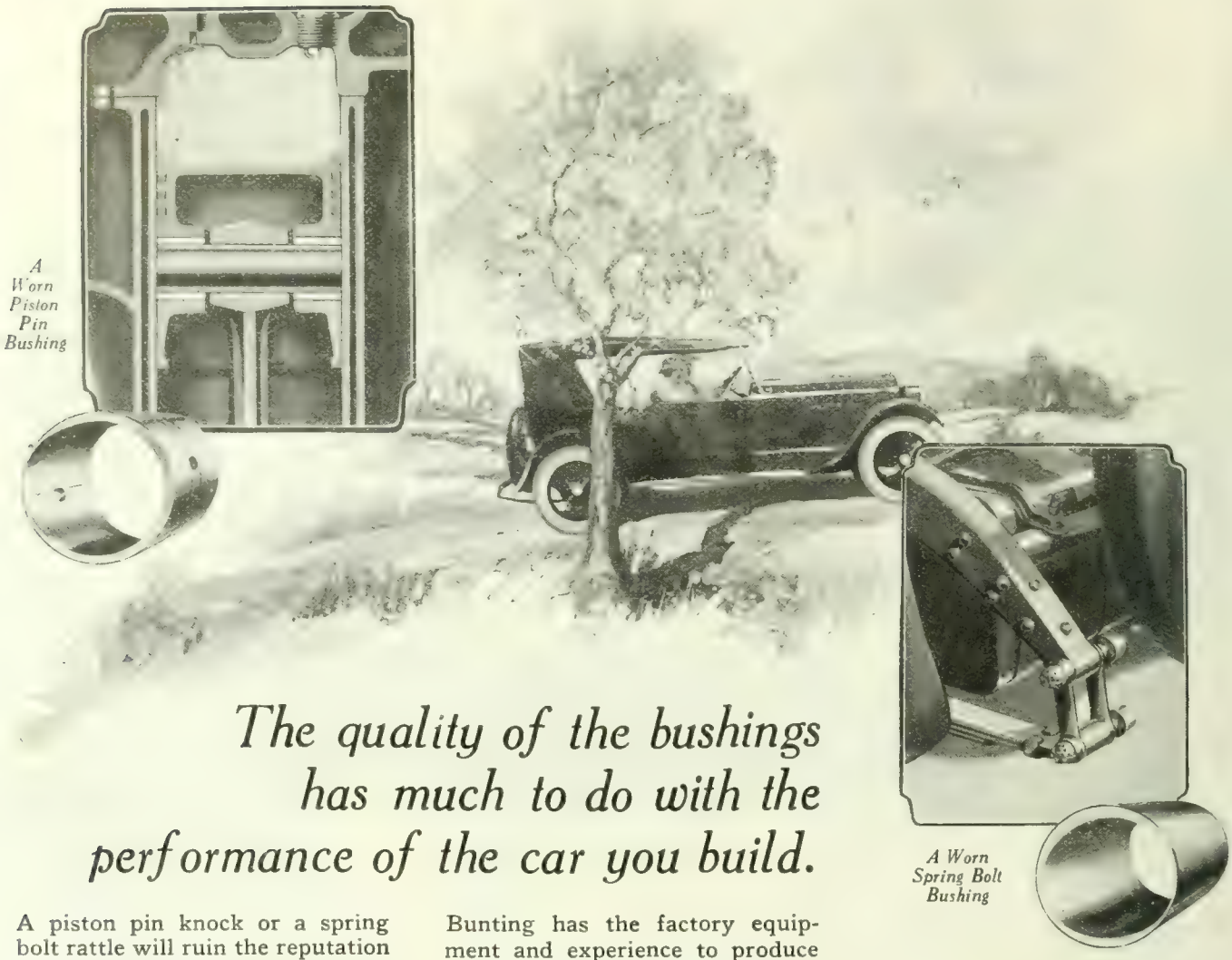
CHAINS **KEYS AND CUTTERS** **HAND MILLING MACHINES**

NEW YORK
L. C. Biglow & Co., Inc.
243 W. 55th St.

BOSTON
George C. Steil
200 Devonshire St.

PHILADELPHIA
R. J. Howison
624 Race St.

SAN FRANCISCO
A. H. Coates Co.
770 Mission St.



A Worn Piston Pin Bushing

A Worn Spring Bolt Bushing

The quality of the bushings has much to do with the performance of the car you build.

A piston pin knock or a spring bolt rattle will ruin the reputation of a car that is one hundred per cent good in other and perhaps more important details. The bronze bushings in any car represent an infinitesimal fraction of its cost, but a big percentage of its performance value.

Bunting Bushings in Automotive mechanisms are accepted by trade and public as an evidence of the car builder's determination to employ only the best in the making of his product.

Bunting has the factory equipment and experience to produce any bronze bushing bearing your need may demand.

Most of your requirements can be supplied from Bunting's list of "Ready Made" bronze bushings. This list includes 268 different sizes of completely finished bronze bushings ready for assembly. "They're always in Stock" ready to ship. Long run prices even on small lots. Write for Stock list L.

For your special order lines Bunting has pattern and tool equipment for over 10,000 different designs and practically unlimited foundry and machine shop capacity.

THE BUNTING BRASS & BRONZE COMPANY

TOLEDO, OHIO

New York
245 West 54th St.
Circle 0844

Chicago
722 S. Michigan Ave.
Wabash 9153

Cleveland
710 St. Clair St., N. E.
Main 5991

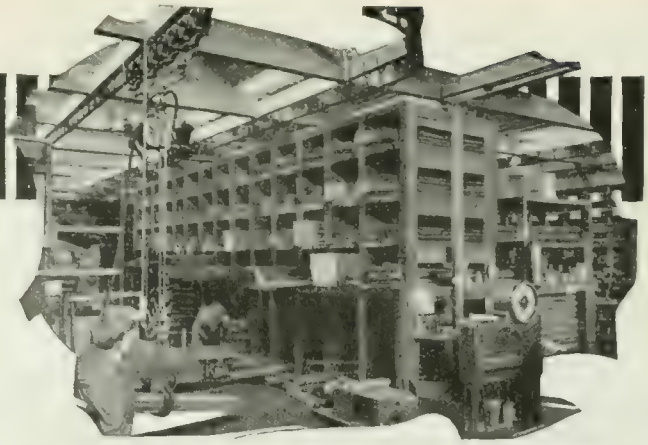
Boston
36 Oliver St.
Main 8488

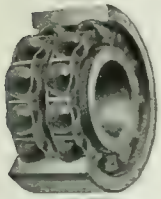
San Francisco
198 Second Street
Douglas 6245

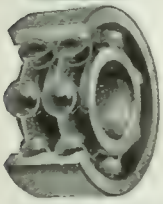
Rice Leaders of the World Association

BUNTING BUSHING BEARINGS

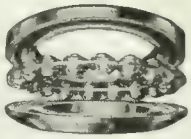
PATENTED







Factors in Strom BALL BEARINGS Supremacy



No. 2—The Raw Stock Room

Here is the impregnable foundation of the perfect performance of STROM ball bearings. STROM bearing steel—made to our own specifications, by America's most expert steel workers, yet subjected to searching chemical and physical tests before use—has that unvarying and exact texture which alone could withstand the untiring watchfulness and machine precision of STROM ball bearing production. Such raw material—plus constructive testing and analyzing continued from bar-stock to shipping-box—is an important factor in determining STROM supremacy.

STROM guaranteed ball bearings, on *new* or *replacement* work, reduce friction to the vanishing point—

"Wherever a Shaft Turns"

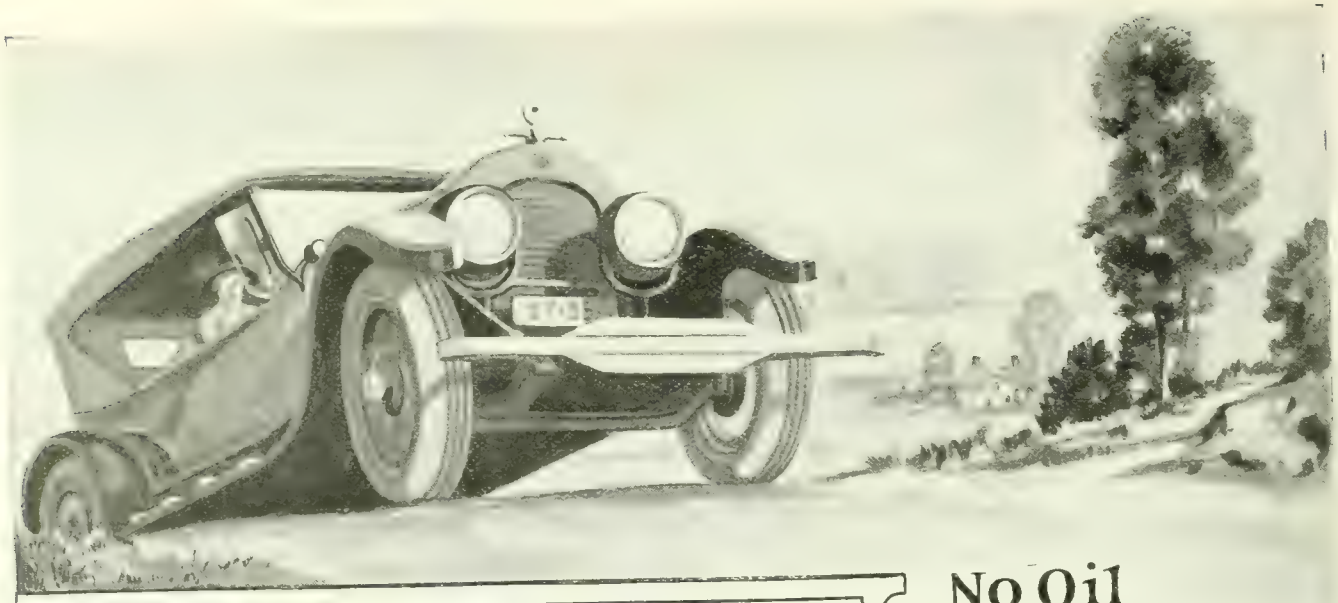
(1976)

Strom BALL BEARINGS

U. S. Ball Bearing Mfg. Co.
(Conrad Patent Licensee)
4533 Palmer St., Chicago, Ill.

An Organization Built for Precision

Scientific in Principle and Practice



A new and better principle in Vacuum Fuel Feed-

Oil-Vac, the Kingston Vacuum Fuel Feeding System, does away entirely with the intake manifold as a suction source, utilizing instead the suction produced by the proper proportioning of the oil circulating pump.

With *Oil-Vac* there is certainty of increased suction with increased engine speed. When the greatest amount of fuel is needed, as in the case of long grades or at high speeds, the greatest amount is actually being delivered to the motor.

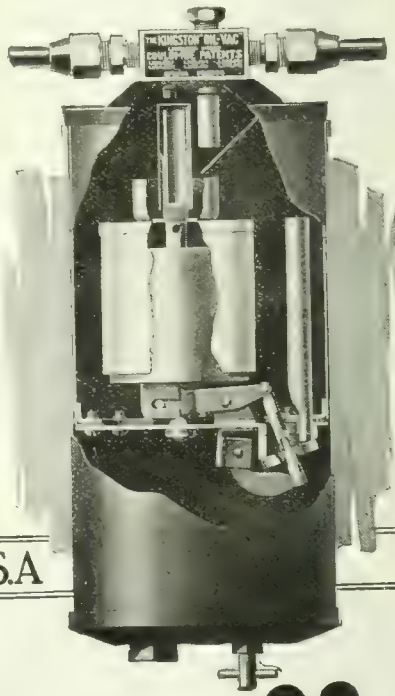
With *Oil-Vac* disturbance of carburetion is at a minimum, and crank case dilution is lessened to a marked degree. Oil runs cooler and lubrication is more efficient.

Automotive engineers generally are taking a deep interest in this *new* principle in vacuum fuel feed. A number of leading manufacturers have already adopted *Oil-Vac* as standard equipment, and many others are investigating its merits. A line to the manufacturers will bring complete information.

No Oil No Vac No Gas

With *Oil-Vac* the vacuum ceases when the oil supply becomes exhausted. No motor should run without oil, and no motor can run without oil for long without serious damage. This is one added feature of importance with *Oil-Vac*, a factor of safety that is worthy of consideration.

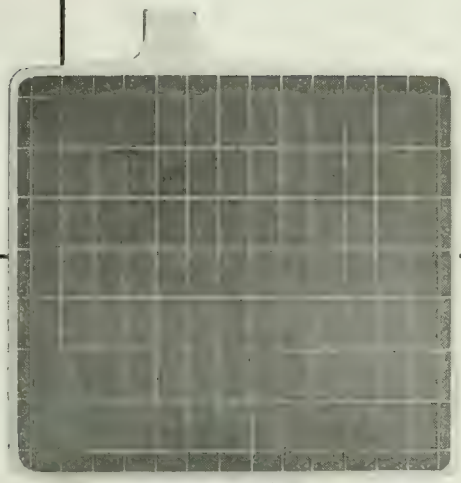
Send for the *Oil-Vac* Booklet



BYRNE, KINGSTON & CO. KOKOMO, INDIANA, U.S.A

Branches
New York, 245 W. 55th St. — Chicago, 1430 Michigan Ave
Dallas, 2218 S. Harwood St. — Detroit, 4610 Woodward Ave
Boston, 15 Jersey St — Los Angeles, 1417 W. Pico St.

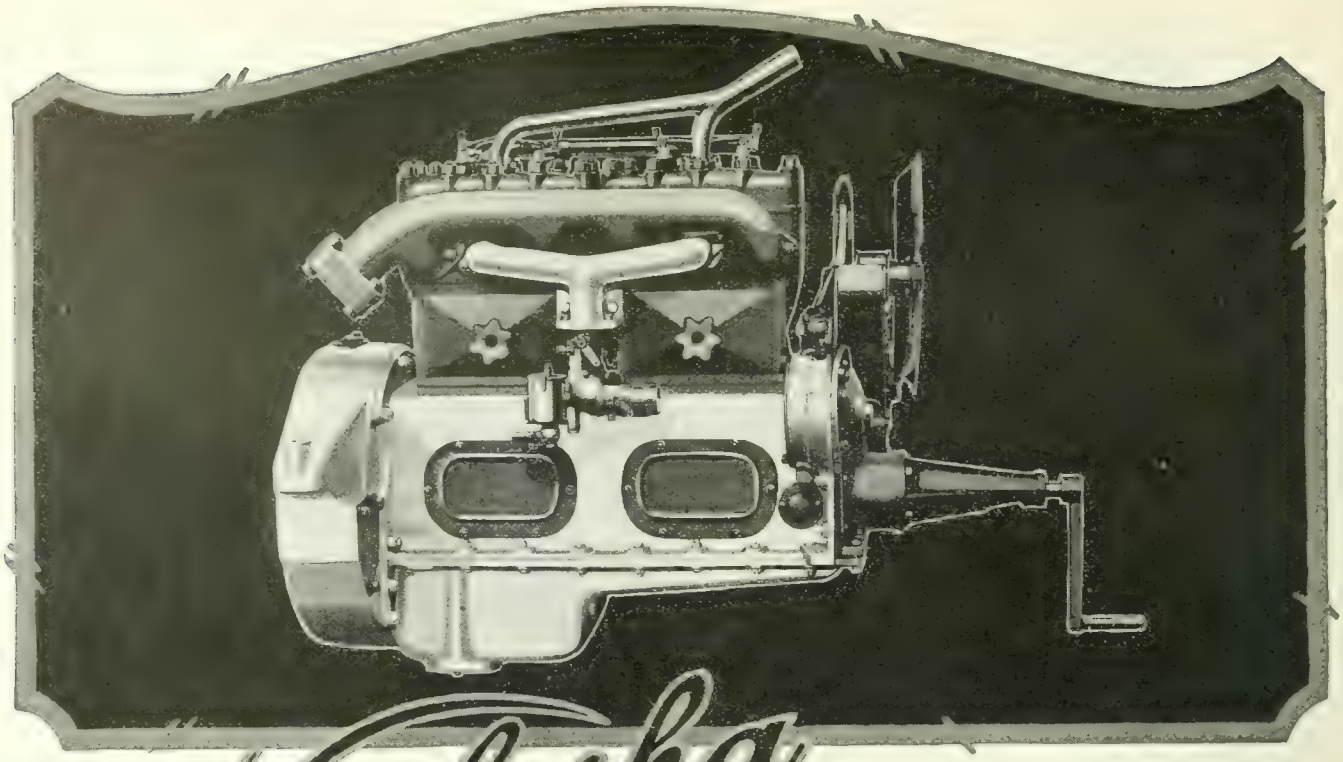
"Oil-Vac"



THE plates in the Westinghouse Battery are a compromise between the so-called thin and thick plates. The weakness of the thin plate (buckling) has been practically overcome. So has the objection to the thick plate, viz., failure of the acid to penetrate to inside active material on high discharges.

WESTINGHOUSE UNION BATTERY CO.
Swissvale, Pa.

WESTINGHOUSE
BATTERIES



Waukesha
TRADE MARK

BUS and TRUCK MOTORS

Even though there exists so many exclusive and distinguishing features in the design, construction and workmanship of the Waukesha Bus and Truck Motor, business men generally, like those in the industry, prefer to acclaim its great economy, and why not?

It has made possible better transportation and hauling at a radically reduced cost. Its existence represents more trips made, more tons moved, more years of compensating working life at decidedly less expense.

Its remarkable performance records are not only worthy of but command the fullest consideration of everyone with whom transportation is a daily problem.

We shall be pleased to forward complete and detailed information to all those making a request.

The WAUKESHA MOTOR COMPANY, Waukesha, Wisconsin

Cost of Reputation

The amount of money spent by this company in advertising, has invariably been overestimated by those unacquainted with the figures.

There are good reasons for this in the fact that Timken publicity has been consistent and long-continued; and still more in the fact that Timken Axles have verified the conservative statements of Timken.

It is not by brilliant advances and sharp retreats but by the steady progress of twenty years—a new idea here, a little added quality there, a constant forward development of axle design—that the name Timken has identified itself with dependability.

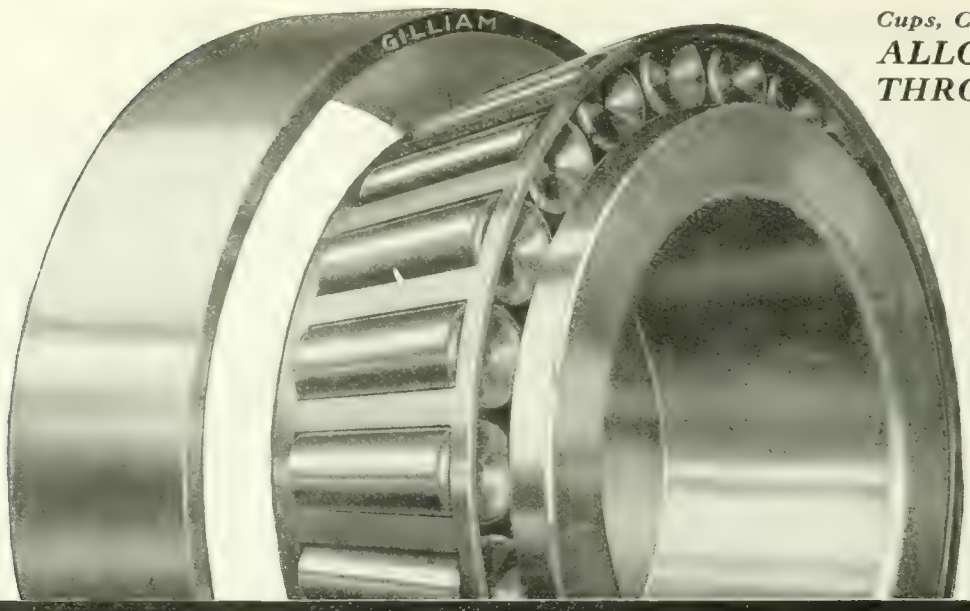
Thus factory vigilance and advertising truthfulness have together worked a reduction in selling cost both for us and for Timken-equipped cars.

The use of Timken Axles by car builders who had for years built their own axles proves not only Timken reputation but also the reasonable cost of that reputation.

THE TIMKEN-DETROIT AXLE COMPANY, DETROIT, MICH.
Sole Representatives in the British Isles:
AUTOMOTIVE PRODUCTS COMPANY, 3, Berners Street, London, W. 1.

Magazine advertising is economical and productive in proportion as it is supported by the word-of-mouth advertising of the buyers.

Cups, Cones, Rollers
ALLOY Steel
THROUGHOUT



The Rollers in GILLIAM Tapered Roller Bearings form true rolling cone lines when in operation, and they do not depend upon the cage to keep them in axial alignment. This is accomplished by the patented feature on the thrust rib of the cone.

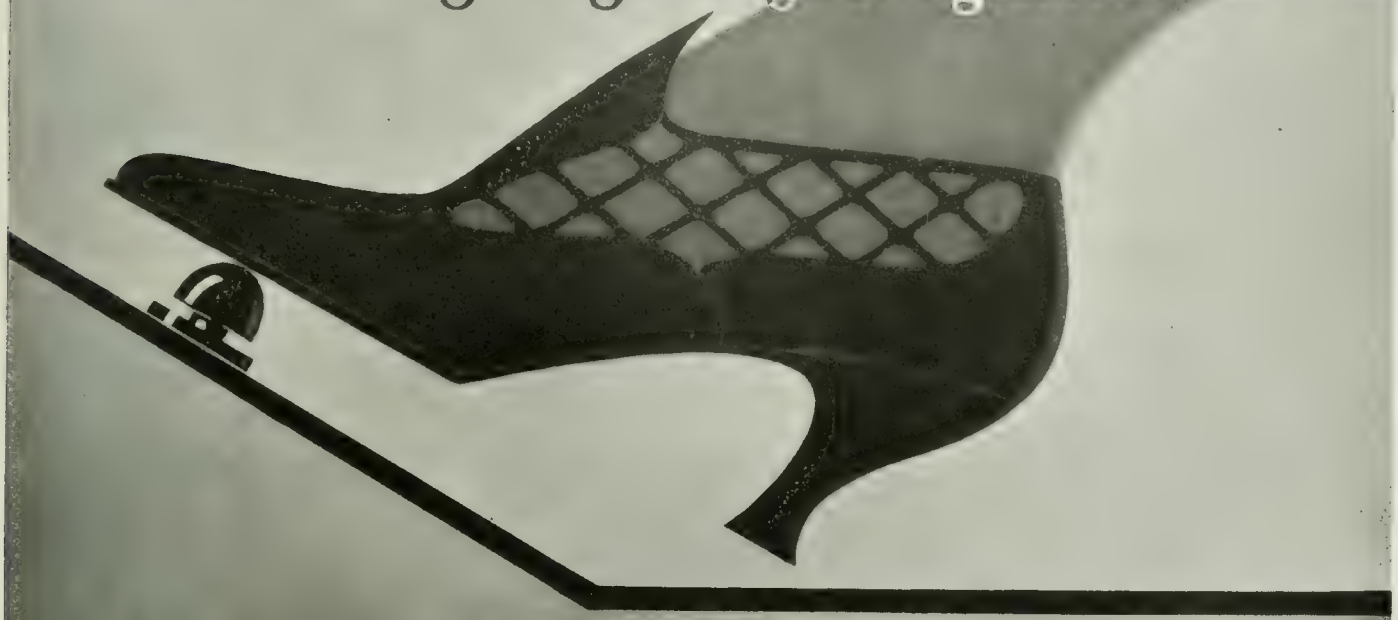
Axle manufacturers using Gilliam Tapered Roller Bearings include: Adams, Clark, Columbia, Flint, Salisbury, Sheldon, Standard Equipment, Torbensen, U.S., Vulcan, Wisconsin.

GILLIAM TAPERED ROLLER Bearings

The Gilliam Mfg. Co. - - Canton, Ohio

Auto-Lite

Starting, Lighting & Ignition



THE superior excellence of the Auto-Lite System is conclusively shown by the fact that between 40 and 50 per cent of all electrically equipped motor vehicles (excluding Fords) are equipped with Auto-Lite.

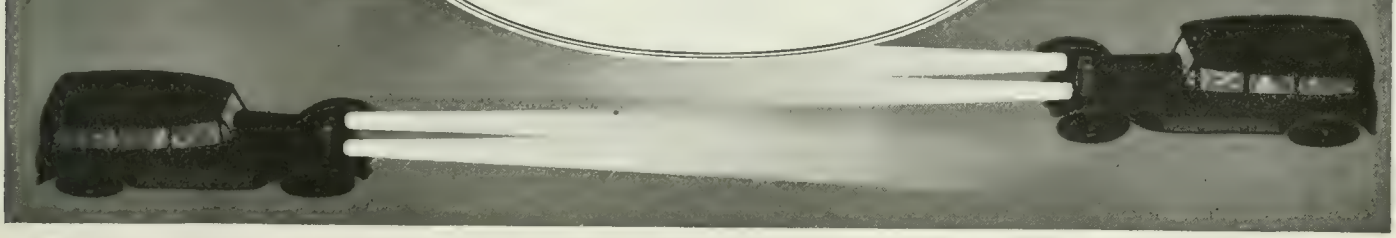
Public confidence in the ability and reliability of the Auto-Lite system results from the years of satisfactory experience of millions of car owners all over the world.

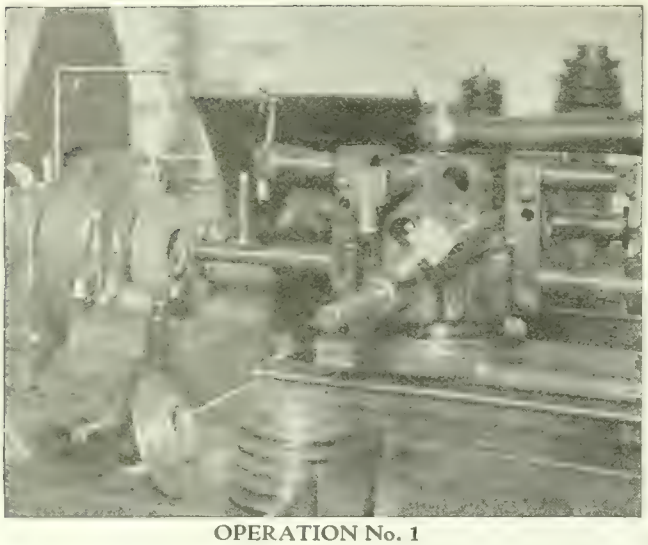
Could Auto-Lite be the largest builder of electrical systems unless the car owners received maximum service and long life with minimum service attention?

THE ELECTRIC AUTO-LITE COMPANY

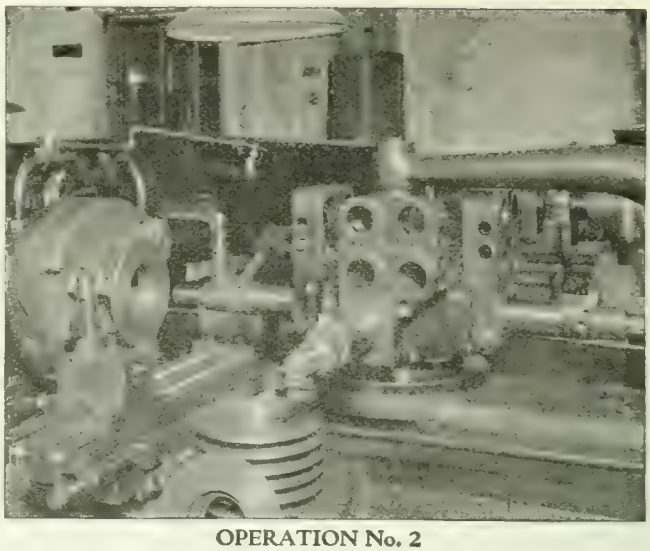
Offices and Works:
TOLEDO, OHIO

Detroit Sales Office:
1309 KRESGE BLDG.



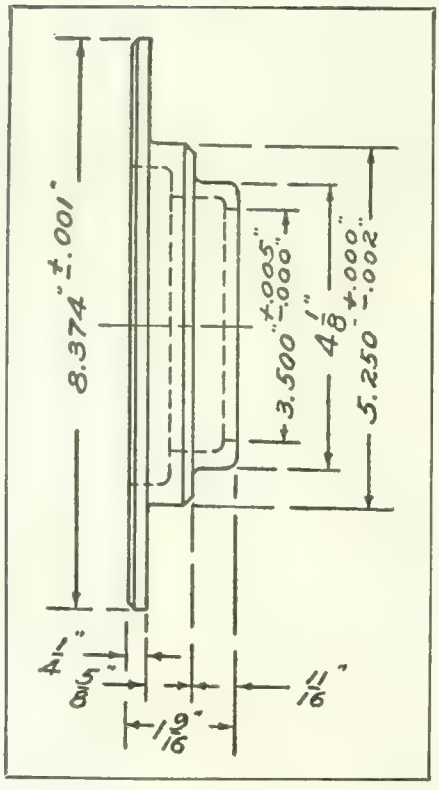


OPERATION No. 1



OPERATION No. 2

41% Increased production— 10% Decreased tool cost



Turning Malleable Iron Wire Wheel Hub Mountings

First cost of Stellite Tools for this Job	$35.46
Scrap Value on Returned Stellite Ends	5.95
Net Cost of Stellite Tools for Set-Up	$29.51
First Cost of Tools of Other Cutting Metals	10.05
Difference in First Cost	$19.46

But—

One Set of Stellite Tools Turned	5,750 Pieces
One Set of the Other Tools Turned	1,754 Pieces
Number of Sets of Other Tools Saved by Investing in One Set of Stellite Tools	2¼ Sets

And—

1 Set of Stellite Tools Turned	5,750 Pieces in 1,030 Hrs.
3¼ Sets of the Other Tools Turned	5,750 Pieces in 1,453 Hrs.
Number of Hours Saved by Investing in One Set of Stellite Tools	423 Hrs.

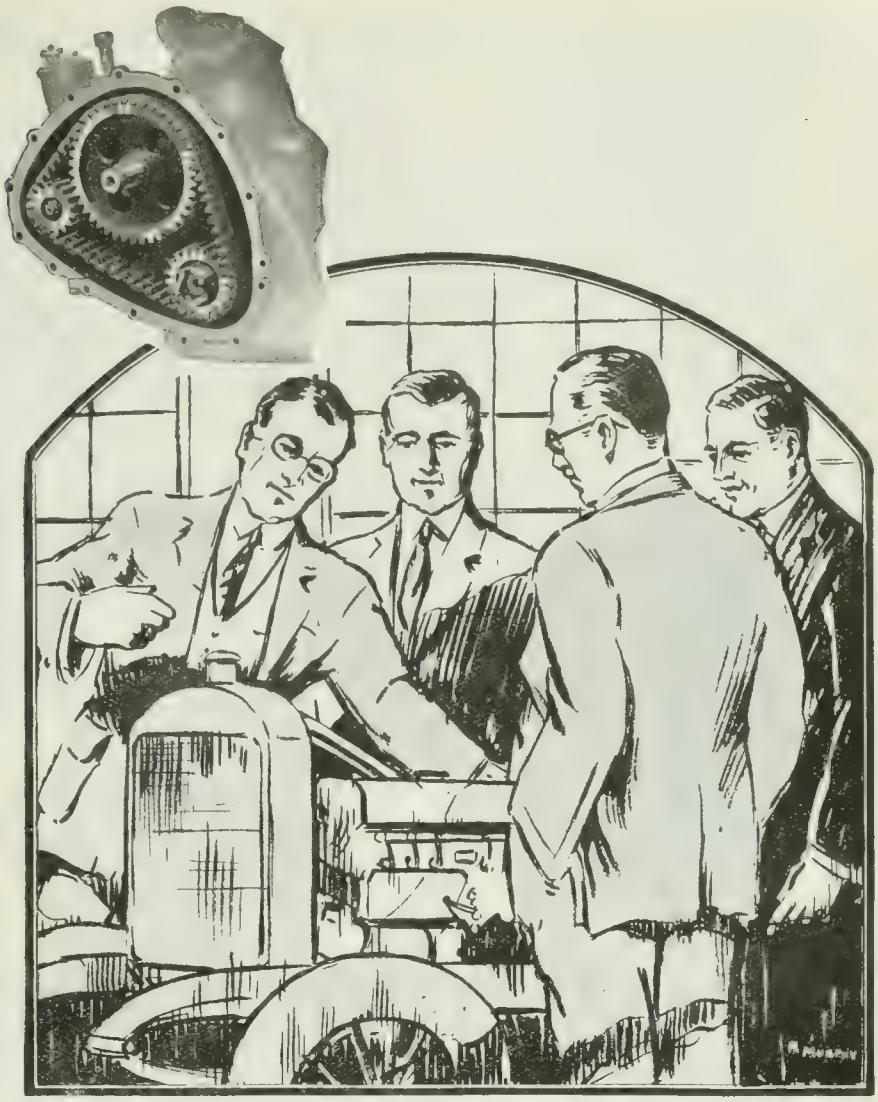
Tell us of *Your Job* and we will tell you of the increased production *You Can Get* and *How to Get It*

HAYNES STELLITE CUTTING TOOLS

HAYNES STELLITE COMPANY

Carbide and Carbon Building—30 East 42d Street, New York

Peoples Gas Building, Chicago General Motors Building, Detroit 4503 Euclid Avenue, Cleveland



Anderson Six
Auburn Six
Barley Six
Cadillac Eight
Case Six
Chalmers Six
Chandler Six
Cleveland Six
Columbia Six
Crawford Six
Davis Six
Essex Four
Flint Six
Fox Six
Hupmobile Four
Hudson Six
Jordan Six
Lafayette Eight
Lincoln Eight
Moon Six
National Six
Northway Four
Oakland Six
Packard Single Six
Packard Twin Six
Rickenbacker Six
Stearns Four
Stearns Six
Saxon Four
Sterling-Knight Six
Studebaker Light Six
Star Four
Templar Four
Winton Six
Continental Motors

Where Engineers Agree

Automotive Engineers work under widely differing conditions. Not all of them seek exactly the same goal. Variety of training and experience naturally leads to differences in their recommendations.

But on some points there is notable agreement between them. Their preference for Morse Silent Chain, for instance, has established our equipment as the dominant form of cam and accessory drive.

A glance at the list of Morse equipped cars shows how pronounced is this preference.

MORSE CHAIN COMPANY

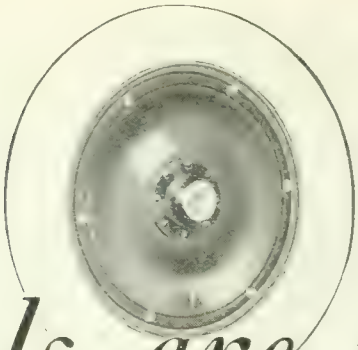
Main Office and Works
ITHACA, NEW YORK

Sales and Engineering Office
DETROIT, MICHIGAN

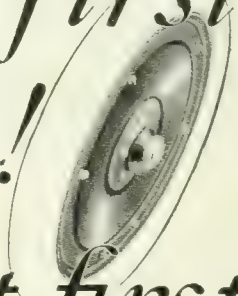
THE CONSTANT PRESSURE ANGLE CHAIN

MORSE

GENUINE SILENT CHAIN



Wheels are the first moving parts seen!



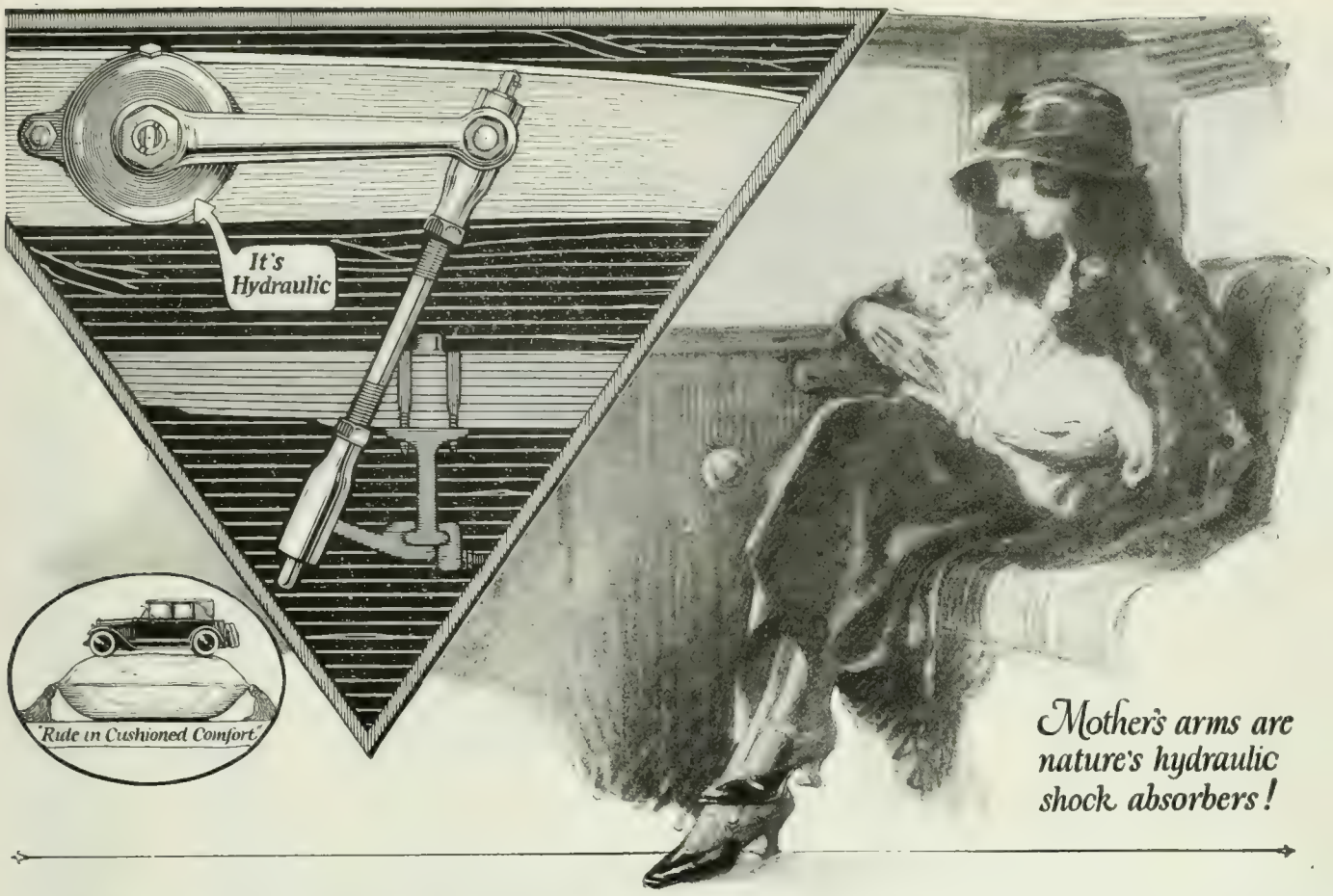
Strengthen that first impression with Tuarc, Disteel or Forsyth, the prevailing steel wheels.

MOTOR WHEEL CORPORATION *LANSING, MICHIGAN*

Wood Wheels · Steel Wheels · Stamps

Tuarc-Disteel-Forsyth

Motor Wheel
PRODUCTS



Ride in Cushioned Comfort

No matter how rough and uneven the road, how long and tiresome the trip, the baby, cradled in his mother's arms, knows neither shock nor fatigue. This is because the mother automatically absorbs the shocks and cushions the child against them with the springy resiliency of her arms.

This same ease and freedom from uncomfortable motor travel will be yours if you equip your car with Hoo-Dyes, for they act on the same principle as mother's arms. This hydraulic spring control compels your car to ride on liquid cushions, and by eliminating the bumps and shocks due to uneven roads makes every mile a mile of cushioned ease.

There is no car so finely made or beautifully balanced that it does not need the cushioned comfort of Hoo-Dye hydraulic control. Hoo-Dyes have brought a new delight to motoring by wiping out all road fatigue.

THE HOUDAILLE COMPANY, 1410 West Ave., Buffalo, N. Y.
Houde Eng. Corp., M'f'r's

Standard Equipment in

Europe	*America*
Alda	Aries
The Austin Motor Co., Ltd.	Lincolns
de Bazelaire	Cunninghams
Chenard & Walker	Mercers
Delage	while many thousands have been applied to
Delaunay-Belleville	Cadillacs
Delahaye	D. F. P.
Farman	G. Irat
La Colombe	Locomobiles
Minerva	Philos
Rochet Schneider	Pierce-Arrows
Scap	Slim
Secqueville & Hoyau	Lafayettes
Unic	Packards
Wolseley Motors Ltd.	Studebakers
	Hudsons
	Buicks
	and many other makes.

For your own health's sake, send for a copy of "How Motor Shocks Affect the Nervous System," by R. Kendrick Smith, M.D.

HOO-DYE
Shock Absorbers
Hydraulic

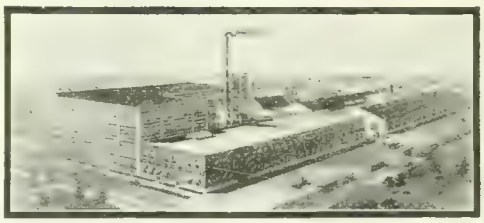
Positive Proof of Consistent Dependability

QUALITY SHAPRINGS

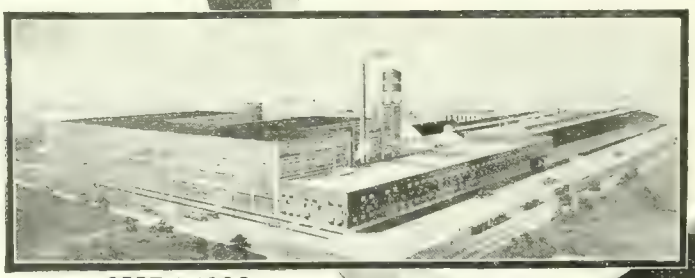
NOV. 30, 1911

DEC. 1, 1912

JUNE. 15, 1915



SEPT. 1, 1916



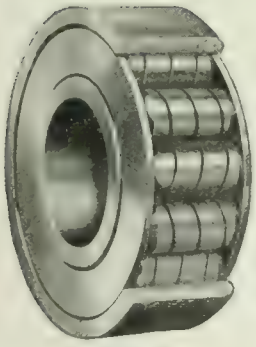
SEPT. 1, 1920

April 1, 1923. Ground broken for $250,000 foundry building. Electric furnaces and special equipment will be installed, designed for a production of over 20,000 piston ring castings per hour. When completed this will be, without question, the most modern and efficient piston ring foundry in the world.

The Piston Ring Company

Muskegon, Michigan

HYATT
Quiet
Roller Bearings



The many engineering refinements that are embodied in the new Gardner are the outcome of the earnest desire of its manufacturers to provide a still greater dependability and economy.

Realizing the many advantages that follow the use of Hyatt roller bearings, Gardner engineers specified these bearings in the rear axle construction.

By carrying the gear load at the differential and the car's weight at the hubs Hyatt roller bearings help to assure for Gardner owners a rugged, quiet, trouble-proof rear axle.

HYATT ROLLER BEARING COMPANY
Newark Detroit Chicago San Francisco

Worcester Milwaukee Huntington, W. Va. Minneapolis Philadelphia
Cleveland Pittsburgh Buffalo Indianapolis

AGATHON ALLOY STEELS

THE average motor car owner little understands or appreciates the tremendous stresses and strains to which the vital parts of his car are subjected while speeding over country roads—up hill and down vale. He has little conception of the grating, grinding, wearing effect of steel upon steel that takes place in axle housing, transmission case and under the hood of his car.

But the car builder knows. And in seventy to eighty of the highly stressed parts of his car he uses nothing but super-steels—alloy steels of such analysis as will best resist wear, shock and strains.

In most of America's best known cars these vital parts are made of one of the many analyses of Agathon Alloy Steels. Each is produced to meet precise requirements. Charts showing analysis and physical properties of nineteen popular alloy steels are given in our booklet, "Agathon Alloy Steels," which will be sent on request.

We have daily production in all kinds of commercial alloy Steels such as—

Nickel, Chrome-Nickel, Uma, Molybdenum, Chrome-Molybdenum, Nickel-Molybdenum, Vanadium, Chrome-Vanadium, Chromium, etc.

Deliveries in Blooms, Billets, Slabs, Bars, Spring Flats, Hot Rolled Strips, etc.

THE CENTRAL STEEL COMPANY, Massillon, Ohio

SWETLAND BLDG. CLEVELAND | BOOK BLDG. DETROIT | PEOPLES GAS BLDG. CHICAGO | UNIVERSITY BLOCK SYRACUSE | WIDENER BLDG. PHILADELPHIA

A Stage-Coach of Today

—with a record of over 300,000 miles of continuous service

Modern successors of the old stage-coaches of '49, sturdy, Delco-equipped Cadillacs today are carrying passengers over plains, deserts and mountain roads.

Day after day, year after year, one of these cars belonging to a fleet of Cadillacs owned by the Red Star Stage Company of San Francisco has made its trips to Half Moon Bay and Pescadero.

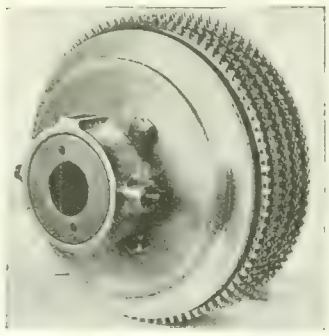
It has rendered more than 300,000 miles of this type of service—a distance equal to twelve times around the world.

This performance is but one of many extraordinary demonstrations of the dependability and endurance of Delco —the World's Foremost Starting, Lighting and Ignition System.

Ever since 1911 when Cadillac introduced to the motor car industry the first complete electrical system—Delco, this pioneer electrical equipment has been used on millions of high-grade motor cars where quality and performance are the manufacturer's only ideals.

DAYTON ENGINEERING LABORATORIES COMPANY
DAYTON, OHIO

Delco



Multiple Disc Clutches.

"DETLAFF"

HOW many engineers know that the Detlaff Model "H" multiple disc clutch is the commercial refinement of the famous U. S. Standardized Class "B" clutch — designed by a coterie of America's foremost engineers?

CUSTOMERS tell us our Model "H" is the most *dependable* clutch on the market. The "VELVET CLUTCH WITH THE BULL-DOG GRIP" is specified on trucks, for instance, destined for out-of-the-way foreign points, where difficulties of Service, or lack of any Service, compel the use of only those units with proven long life records.

THE friction elements are interchangeable for U. S. Standardized Class "B" and Detlaff Model "H." Distributing depots for parts are located in London, Eng.; New York, Baltimore, Chicago and San Francisco.

A. J. DETLAFF CO.

Detroit, Mich.

S. A. E. Employment Service

The following announcements are published for the benefit of members of the Society and the convenience of companies in need of men. No charge whatever is made for this service. In the case of items prefixed by an asterisk further information is withheld at the request of the company or individual making the insertion, but written communications bearing the number of such items will be forwarded by the office of the Society. Applications for positions from non-members must be endorsed by a member of the Society.

No announcement will be repeated in these columns unless specific information is at hand that the respective member is available or the position unfilled.

To put available men and employers in touch with each other quickly, this column is supplemented twice weekly by a bulletin giving the latest information with regard to Men and Positions Available. The bulletin will be mailed to members and employers on request.

It is suggested that for quick action in securing men or positions there be specified for publication the name and address, a post-office box number or a general mail delivery address. If applications are confidential, the Society will forward replies through an index number.

For the good of the service members securing or filling positions or companies securing men through these columns are urged to send advices to this effect to the office of the Society promptly.

Considerable time can be saved in securing a position if the following items of information are given in registering with S. A. E. Employment Service.

1. Date
2. Name in full
3. Present mail address
4. Telephone number
5. Present telegraph address
6. Permanent mail address
7. Telephone number
8. Married or single
9. Nationality
10. Age
11. Height
12. Weight
13. State of health
14. Education (Give schools and colleges attended, courses taken and duration of each course)
15. Previous employers (Give names, addresses, term of employment with each, your title and the nature of the work done)
16. Are you employed at present?
17. References (Give names and address of three or four persons not related to you and with whom you have been directly associated)
18. What societies, clubs or associations are you a member of?
19. Salary wanted per week, month, year
20. What general classifications do you wish to be listed under? (List in order of preference. For example: General Manager, Works Manager, Research Engineer, Production Engineer, etc.)
21. Do you wish your name and address published in your announcement?
22. Do you wish to use a post-office box number? (If so, arrange with your postmaster for the use of a box and send the number of the box to us, giving town and state)
23. Is your name to be withheld from publication? (In this case your announcement will be run under an index number and replies will be forwarded through the office of the Society)
24. Prepare copy for insertion in THE JOURNAL and Bulletin. (Make it as complete and as concise as possible)
25. Any preference as to location?
26. When will you be available?

MEN AVAILABLE

0942 CHIEF INSPECTOR, CHIEF DRAFTSMAN OR ASSISTANT ENGINEER; 15 years' experience with prominent automotive companies. Technical graduate. Experimental work. Residence, Detroit; location, Middle West preferred.

0987 CONSULTING AND DESIGNING ENGINEER Graduate of Cornell University in electrical and mechanical engineering with 20 years' experience in stationary, automobile and Diesel engines, design and production, jigs, etc., wishes work in inventing, developing or design, either at his home or in reach of Larchmont, N. Y.

0988 ENGINEER Technical and practical man who has made a specialty of engine governors desires to make a connection as assistant chief engineer or suitable executive post. Residence, New York City; location, immaterial.

(*Continued on p. 70*)

A New Ease to Car Operation

Clutch performance plays a most important part in car operation. Easy, silent and effortless gear shifting depends largely upon clutch action—it is the clutch which governs the smoothness, quietness and agility with which the motive power is transmitted to the driving shaft.

The Long Clutch brings a new ease to car operation because it provides these essentials in a degree never before attained. When operating a car equipped with the Long Clutch, the driver need never know the embarrassment and confusion of clashing, grinding gears. Engagement takes place with a gliding motion in which all tendency to jerk or grab is eliminated. Moreover, this goodness is permanent, for the Long Clutch never needs adjustment.

Long Manufacturing Co., Detroit, Mich.

LONG CLUTCH

LONG PRODUCTS—RADIATORS AND CLUTCHES

The
Pictures
Tell
The Story

The
Highland
Model D
Cab
Meets Every
Trucking
Condition

THE
HIGHLAND
BODY MFG. CO.
410 Elmwood Place
Cincinnati,
Ohio

S. A. E. Employment Service

Continued

MEN AVAILABLE

1036 Automotive Engineer; practical and technical education; 20 years' experience in designing, production, research, testing, consulting and teaching; part time if desired; high-grade man capable of getting results. Residence, New York City; location, New York City or vicinity preferred.

1039 Assistant to Executive; university graduate with 6 years' experience with motor car builders; competent to take charge of service work, purchases and stores stock, and to assist in engineering. Residence, New York City; location, New York City or vicinity preferred.

1083 Engineer who has had 10 years' experience on Diesel engines and has designed and built complete line with 30,000 hp. now in operation wishes to establish a connection with an engine builder. Residence, Cleveland; location, immaterial.

1096 Production Manager and Mechanical Engineer would consider a position requiring initiative and ability to handle production engineering problems successfully. 12 years' executive experience in automotive and allied industries; supporting testimony available. Residence, Brooklyn; location, New York City or vicinity.

1102 Engineer; truck and truck fleet operation; would prefer a position in commercial research or sales development. Technical training. Factory sales work or pioneering of a new product. Residence, Pittsburgh; location, New York City or vicinity preferred.

1174 Manager of Sales, District Manager or Sales Engineer. Technical graduate with 12 years' shop, sales office and sales engineering experience on the road. Experienced in specialty products applicable to automotive industry. Residence, Philadelphia; location, Philadelphia only.

1180 Chief Inspector; technical education; 11 years' executive experience with prominent gas and automobile engine builders. Capable of supervising, organizing, systematizing and tooling inspection efficiently and diplomatically from the foundry to the test stand. Residence, Indiana; location, immaterial.

1185 Research or Chief Engineer, General or Production Manager; wide experience with prominent companies. Also airplane experience. Residence, Long Island; location, New York City or vicinity.

1206 Production Manager; 10 years' association with prominent manufacturers of metal and wood products. Extensive supervisory experience in machinery construction, also quantity production involving repetition operations of metal products. Practical man and capable organizer and administrator with college and practical training. Residence, New York City; location, immaterial.

1208 Designing Engineer; 5 years' experience on passenger cars, trucks, engines and railroad air brakes as chief draftsman, also some experimental experience. Residence, New York City; location, New York City or vicinity.

1217 Chief or Executive Engineer. Technical graduate with 12 years' experience in automobile engineering; especially versed in eight-cylinder design with successful experience in chassis and body design. Has made a thorough study of cost reduction in manufacturing from engineering standpoint and is experienced in complete car development from the experimental stage to production. Residence, Indianapolis; location, immaterial.

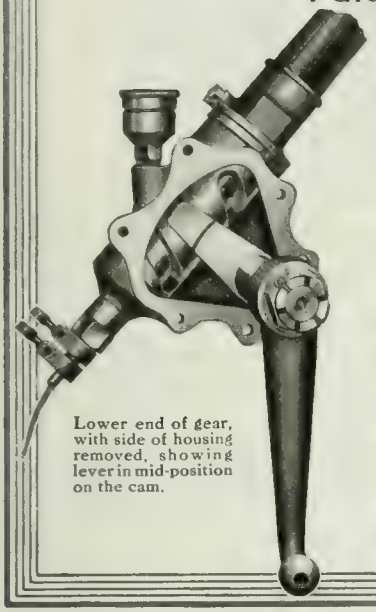
1219 Chief Engineer of large corporation building Diesel and automotive engines and steam turbines for 8 years, desires a position with a company having a research department that would like to develop high-speed Diesel engines for automobiles and tractors. Residence, Iowa.

1220 Engineer who was formerly with a large tractor builder in Ohio in an experimental and drafting capacity desires a similar position with an automobile or engine company. Wide experience with high-speed type engines. Residence, Ohio; California or other Western States preferred.

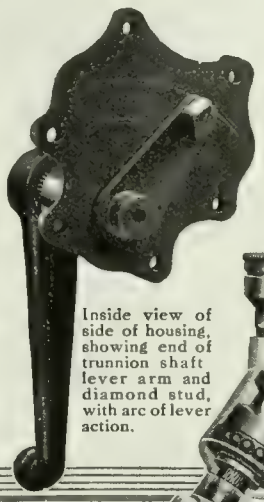
(*Continued on p.* 72)

See announcement at the head of the S. A. E. Employment Service column, p. 68

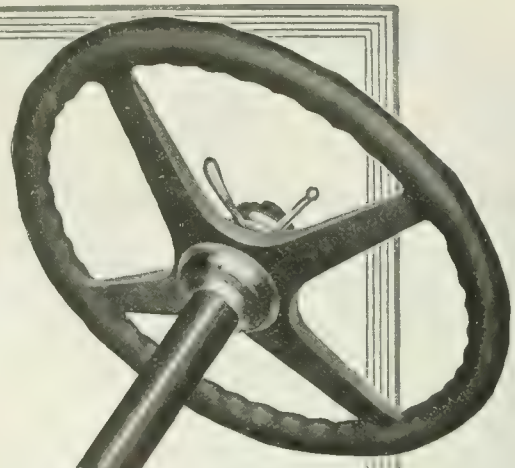
ROSS
Cam & Lever Steering Gear
Patent Pending

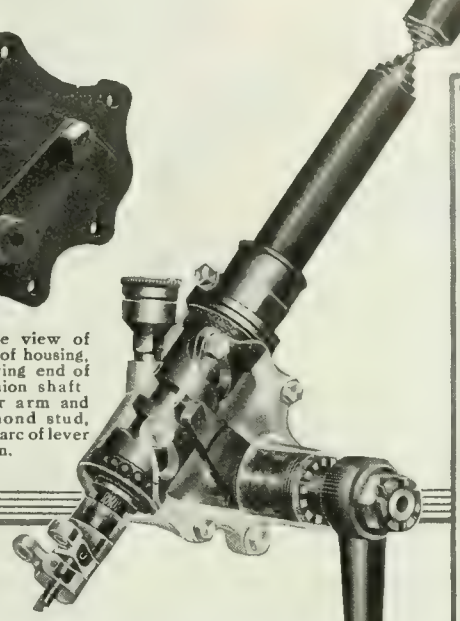


Lower end of gear, with side of housing removed, showing lever in mid-position on the cam.

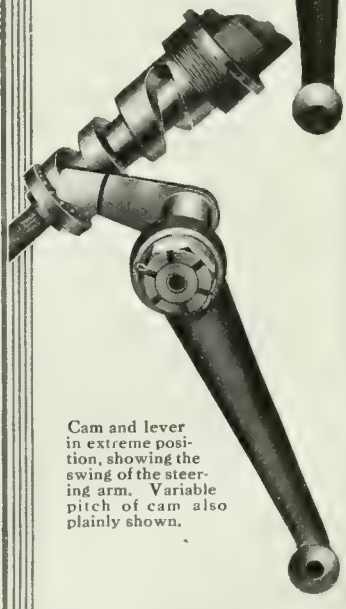


Inside view of side of housing, showing end of trunnion shaft lever arm and diamond stud, with arc of lever action.





Housing entirely removed, showing variable pitch of the thread of the cam and relation of cam and lever in mid-position.



Cam and lever in extreme position, showing the swing of the steering arm. Variable pitch of cam also plainly shown.

This new steering gear is so radically different in principle and design that many engineers were frankly skeptical about our claims for it. However, demonstrations have convinced them and they are now enthusiastic over this wonderful combination of small size and simple construction with power, reliability and easy steering.

The gear is so irreversible in mid-position that practically all road shock is eliminated. The long lever arm inside the gear provides the easiest kind of steering under all conditions and the car holds the road with the least effort on the part of the driver.

The variable pitch of the cam offers a unique accelerated action which facilitates quick handling in making turns and in swinging back into flat-to-the-curb parking position.

Adapted for passenger cars, motor trucks, motor buses, fire trucks and tractors. Write for special information desired.

ROSS GEAR & TOOL COMPANY
730 Heath St., Lafayette, Indiana, U.S.A.

ROSS STEERING GEARS

THE STEERING GEARS THAT PREDOMINATE ON MOTOR TRUCKS

Deppé Motors Corporation Superheated Gas System

(Patented)

This system in cars of the 3000 lb. class with engine displacement of 250 cubic inches gives results as follows:

With 100 lb. Compression

Fixed Superheated Gas Mixture

Fixed Adjustments in All Parts with Controlled Combustion

Develop maximum speed of 60 M.P.H.

Twenty-two miles per gallon with existing or any future motor fuels.

Sixteen hundred miles per gallon of lubricant.

Ten to 30 M.P.H. in 9 seconds.

Radiator water normally around 130° F.

NO THERMOSTATS

Easy starting, no loading.

Practically eliminates carbonization.

No preignition, no autoignition.

No so-called detonations.

Eliminates vibration due to fuel conditions.

Practically eliminates lubricating oil dilution.

No overheating of metals.

Practically eliminates valve grinding.

Practically eliminates bearing adjustments.

Practically eliminates spark-plug troubles.

PRACTICALLY ELIMINATES GEAR SHIFTING.

Deppé Motors Corporation

151 Church Street

New York City

S. A. E. Employment Service

Continued

MEN AVAILABLE

1229 Automotive Engineer; Cornell graduate with 8 years' experience in the design and development of engines and automobiles; now chief engineer of Eastern company but wishes to make a change; responsible executive position desired. Available on reasonable notice. Residence, Connecticut; location, East or Middle West preferred.

1230 Automotive Engineer; Engineering executive with a technical education and 12 years' experience in the original design of complete cars and factory methods desires a position with a car, engine or parts manufacturer, or as sales engineer. Residence, Cleveland; location, immaterial.

1231 Assistant Engineer or Chief Draftsman; 6 years' experience; thoroughly familiar with the design, construction and production of motor trucks. Available in 2 weeks. Residence, Pennsylvania; location, immaterial.

1232 Instructor with several years' experience in practical work wishes a position in an engineering college as instructor in some line of automotive or transportation work. Residence, Illinois; location, Central West.

1233 Sales Manager now located in Detroit and possessing a wide acquaintance among automobile companies, desires to supervise sales or act as a district representative for a parts manufacturer. Residence, Detroit; location, Middle West preferred.

1235 Service Manager; high-grade man with experience in service merchandising methods; stock and shop arrangement and management. Graduate mechanical engineer with 10 years' experience in truck maintenance and service work. Residence, suburb of New York City; location, New York City.

1246 Factory Manager, Production Engineer, Superintendent or Sales Engineer; technical graduate; 17 years' executive experience with mechanical and electrical accessories including storage-batteries. Capable organizer. Familiar with modern manufacturing and cost methods. Residence, New Jersey; location, immaterial.

1247 Retail Sales Executive; University graduate, aged 34, with extensive experience in service, sales and sales promotion, seeks a broader opportunity with location in New England. Present yearly earnings are in excess of $6,000 as manager of a branch doing a large volume of business. Has introduced and developed successful sales plans.

1250 Executive with organization ability assuring a quality product at a minimum cost; leadership that inspires loyalty, harmony and confidence; 17 years' experience in varied industries; 11 years with an exclusive automobile company. Excellent references. Residence, Buffalo; location, northern United States.

1251 Automotive Engineer Technical graduate with 20 years' continuous experience on the board and as a supervisor of machine and tool design, wishes a position as chief or assistant chief engineer, chief tool designer or master mechanic. Residence, Chicago; location, Middle West.

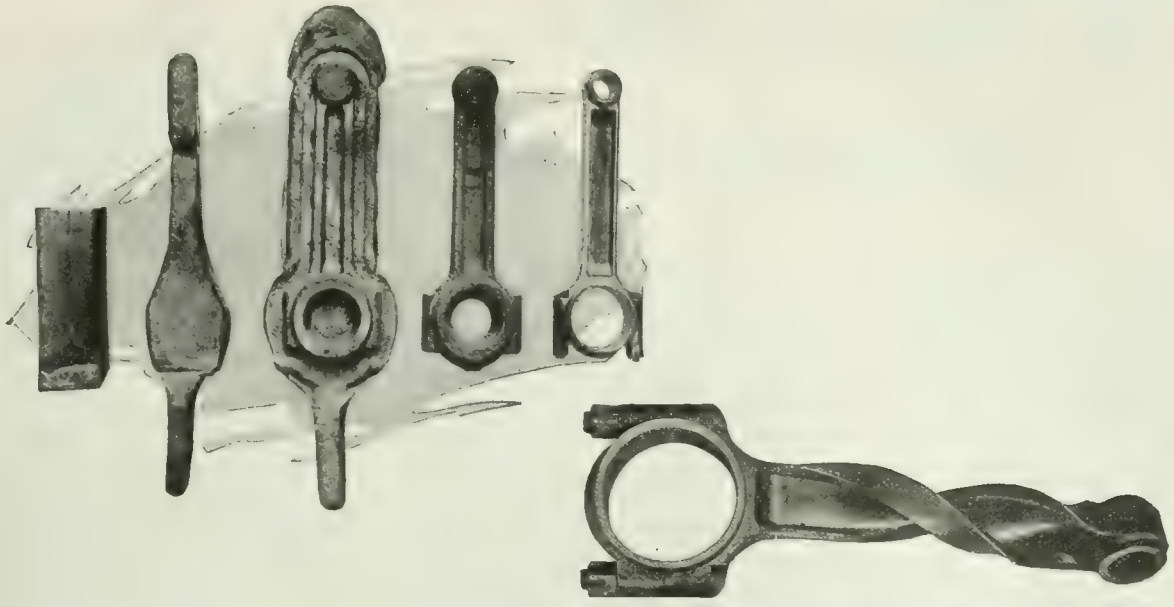
1255 Sales Executive with 19 years' engineering and sales experience in automotive industry who is now sales manager, desires to make a change for personal reasons. Competent to handle national sales and advertising of engines, motorbuses or any parts, or accessories on passenger cars, trucks or tractors; available in two weeks. Residence, Middle West; location, immaterial.

1257 Mechanical Engineer 29 years old and experienced in production and design wishes a position in the production department of a company manufacturing transmissions and differentials. Residence, Pittsburgh; location, immaterial.

1258 Engineer, has held responsible positions as tool designer, research, engine designer, production, sales engineer and consulting engineer. Residence, Ohio; location, Cleveland preferred.

(*Continued on p. 74*)

See announcement at the head of the S. A. E. Employment Service column, p. 68.



Forgeability, Machineability and Toughness of Vanadium Steel

THE Curtiss Airplane Connecting Rod, of which approximately 150,000 were furnished for Curtiss OX airplane engines, affords an excellent illustration of the forgeability, machineability and toughness of Vanadium Steel.

Note the unretouched photographs of progressive stages in the production of this well-known connecting rod.

The finished rod was twisted cold to prove the remarkable toughness of Vanadium Steel.

This distorted connecting rod has the following physical properties:

Elastic limit	125,000 lbs. per sq. in.
Tensile strength	138,000 lbs. per sq. in.
Elongation in 2"	20%
Reduction of area	64%

For every steel purpose demanding exceptional strength, toughness and machineability, there is a Vanadium Steel. Our Metallurgical Engineers will be glad to help you study the problem and select a better steel for your purposes.

VANADIUM CORPORATION OF AMERICA
New York, 120 Broadway Detroit, Book Building

VANADIUM STEELS

for Strength, Toughness and Durability

ZENITH

"The question of saving gasoline should be accomplished, first, by knowing that the carburetor is right for the particular truck and that if any adjustments are to be made, that they will be made by a capable carburetor man. *Better still, if possible, use a non-adjustable carburetor.*"

Extract from address made by E. E. LaSchum, General Superintendent, American Railway Express Company, before Seventh Annual Convention, International Retail Druggists Associa-

Over 160 American Automotive Manufacturers have solved this problem by adopting Zenith Carburetors, because, when the proper jets have been chosen to give the best performance, *they become fixed parts of the carburetor, not subject to outside manipulation.*

ZENITH - DETROIT CORPORATION

Manufacturer of

ZENITH CARURETORS

DETROIT, MICHIGAN

Branches: New York—Cleveland—Chicago

S. A. E. EMPLOYMENT SERVICE

Continued

MEN AVAILABLE

1260 TECHNICAL GRADUATE, has held positions of assistant chief engineer, assistant production manager; domestic and foreign experience on water and air-cooled engines, airplanes and motorcycles; also experimental work and sales. Residence, New York City; location, immaterial.

1262 METALLURGICAL ENGINEER, able to take full charge of laboratories and production or as factory manager in plants making hardened steel parts. Residence, New Jersey; location, immaterial.

1263 SERVICE ENGINEER; over 16 years' experience in all departments as executive, organizer and efficiency expert in passenger-car and truck details; experienced in promotion work, the standardization of service-station equipment and methods, the installation of flat-price cost system on repairs, etc.; truck factory organization experience. Residence, New York City; location, immaterial.

1264 DESIGNING AND RESEARCH ENGINEER; 11 years' experience on four and six-cylinder truck and automobile engines; has held positions of chief and experimental engineer; technical education. Residence, Wisconsin; location, Middle West preferred.

1266 AUTOMOTIVE ENGINEER with 20 years' experience and capable of taking complete charge of engineering department, engines or complete chassis. Wishes position offering proper opportunities. Reliable, energetic, and has initiative. Residence, Rochester.

1271 HIGH-GRADE AUTOMOTIVE ENGINEER with a broad and successful record in engineering, manufacturing and factory organization; a pioneer in the automobile, truck and tractor industries. Residence, Western United States.

1272 YOUNG GRADUATE MECHANICAL ENGINEER with 4 years' experience in service work and 9 months as instructor in automobile mechanics, desires to establish a connection with an automobile company in a production or engineering capacity. Willing to start with modest salary. Residence, Missouri; location, immaterial.

1273 TECHNICAL MAN, 25 years old who will graduate this year in automotive engineering and has had 2½ years' experience in automobile service-station and machine-shop work wishes to locate in engineering or factory service department. Residence, Atlanta; location, immaterial.

1275 ENGINEER with many years' experience and an extensive acquaintance among engineering executives wishes to represent in the Chicago territory the manufacturer of high-grade automotive product that must be backed by a responsible producer and publicity promoted by adequate advertising and sold to jobbers or quantity users. Residence, Chicago.

1280 ENGINEER OR SALES EXECUTIVE; 20 years' experience in the design, construction and sale of vehicles of various types and accessories; wide acquaintance in industry; excellent references; part or entire time; has engineering office in East at present; has specialized in the development of new machines and parts; compensation proportional to results. Residence, Pennsylvania; location, East preferred.

1281 CHIEF RESEARCH OR PRODUCTION ENGINEER OR CHIEF INSPECTOR; wide general mechanical engineering experience; automotive work a specialty in the maintenance and repair of a large fleet of tanks, trucks and automobiles; is an expert research engineer, with the ability to test all kinds of vehicles and possesses a sound knowledge of factory organization and inspection methods; also an expert designer of engines; is tactful with labor, a good mixer and ambitious. Residence, New York City; location, immaterial.

1283 EXECUTIVE; successful record in the manufacture of tools and automotive parts on a large scale; specialty, maximum quality production at a minimum cost; best of references. Residence, Illinois; location, Chicago or vicinity preferred.

(*Continued on p.* 76)

See announcement at the head of the S. A. E. Employment Service column, p. 68.

1 T. A. Willard—who has done and is doing more for storage battery improvement than any other one individual.
2 The Willard Organization—for fifteen years leaders in storage battery manufacture and distribution.
3 The Willard Laboratories—physical, chemical, mechanical and electrical—the finest equipment for battery research in the country.
4 The Willard Factory—with the size, resources and volume for quantity production to a high quality standard.
5 Original Equipment on 135 makes of motor cars; 93% have always used Willard Batteries.
6 The Friendship of 20,000 car dealers.
7 The Good Will of 10,000,000 car owners.
8 The leading Wood-Insulated Battery.
9 The only Threaded Rubber Battery.
10 The most extensive and long-continued and consistent national advertising.
11 The most efficient co-operation with the dealer's local advertising.
12 Membership in the original and most efficient national battery service to car owners.

Back of the Sign

6—Friendship

We can truly say the car dealers of the country are our friends.

They send their owners to Willard Service Stations because they know that Willard Dealers will give them the kind of service which they should have.

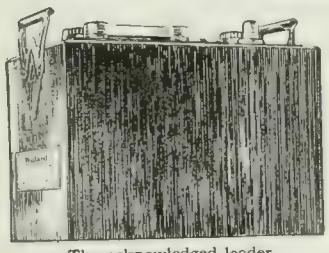
They believe in Willard because they see at first hand the performance of Willard Threaded Rubber Batteries on their cars or on the cars of their neighboring dealers.

And they know from past experience that the Willard Dealer must first, foremost and all the time make good with the owners of Willard Batteries, and the dealers who sell Willard equipped cars.

This is a standardized, organized, efficient service cheerfully rendered to any dealer or owner no matter what make of battery he has.

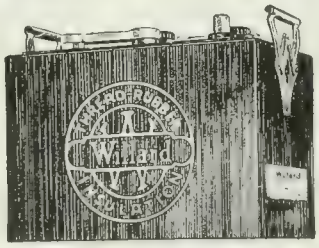
WILLARD STORAGE BATTERY CO., Cleveland, O.
Made in Canada by the
Willard Storage Battery Co. of Canada, Limited, Toronto, Ontario

Willard STORAGE BATTERIES



The acknowledged leader of wood-separator batteries for fifteen years.

Original Equipment on 135 Makes of Motor Cars



The Threaded Rubber Battery that created a new standard of battery value.

MATHER SPRINGS

Standard of the World

The shortest cut to getting your full money's worth in the things you buy is—Quality.

Genuine Made Only By

The Mather Spring Co.

Toledo, Ohio, U. S. A.

S. A. E. Employment Service

Continued

MEN AVAILABLE

1284 Chassis Engineer. Designer, or Chief Draftsman; 12 years' experience in designing chassis, engines, axles and transmissions; also in production; has been connected with some of the most prominent passenger-car companies as assistant engineer, chassis engineer and chief draftsman. Residence, New Jersey; location, immaterial.

1286 Assistant to Chief Executive, Sales or Production Engineer; man with a wide general mechanical engineering experience in the United States and Europe, technical training, experience in the automotive and allied industries, and electrical experience, desires position with car, engine or parts manufacturer. Would represent firm in Europe or the East. Residence, New York City.

1291 Works Manager, or Assistant to Executive; engineering graduate; experience covers entire automotive field; possesses a sound knowledge of factory administration, corporation law and finance; is a capable organizer and administrator with practical training of modern manufacturing methods and labor management. Residence, New York City; location, immaterial.

1292 Sales Manager; 16 years' experience in the automotive field; technical education; wide advertising experience, sales promotion, efficient modern merchandising methods; can take entire charge of accessory proposition if desired, or render valuable constructive assistance. Residence, New York City; location, immaterial.

1293 Lubrication Engineer with 10 years' experience in calling on automotive manufacturers is open for immediate proposition. Residence, Toledo; location, Middle West preferred.

1294 Research or Sales Engineer; wide experience; has been with prominent automotive companies in research, experimental and dynamometer work; college education. Residence, Ohio; location, immaterial.

1295 Automotive Engineer; thorough technical education; 10 years' practical experience as designer and executive in charge of design; resourceful, thorough and diplomatic and possesses the ability to get desired cooperation from other departments. Residence, Philadelphia; location, immaterial.

1303 Mechanical Engineer; technical graduate with 10 years' experience in developing processes, production methods and plant layouts for manufacturers of interchangeable parts, machine tools and wood products, is now available. Residence, New Jersey; location, Eastern States or abroad.

1305 Factory Manager, Chief Engineer, or Production Manager; technical graduate; 15 years' successful experience in the management and engineering of industrial plants producing high-grade interchangeable parts. Available on short notice. Residence, Connecticut; location, southern New England, eastern New York or New Jersey preferred.

1306 Assistant Chief Engineer; 10 years' executive and designing experience; thoroughly familiar with the design and construction of complete passenger cars, trucks and engines. Residence, Chicago.

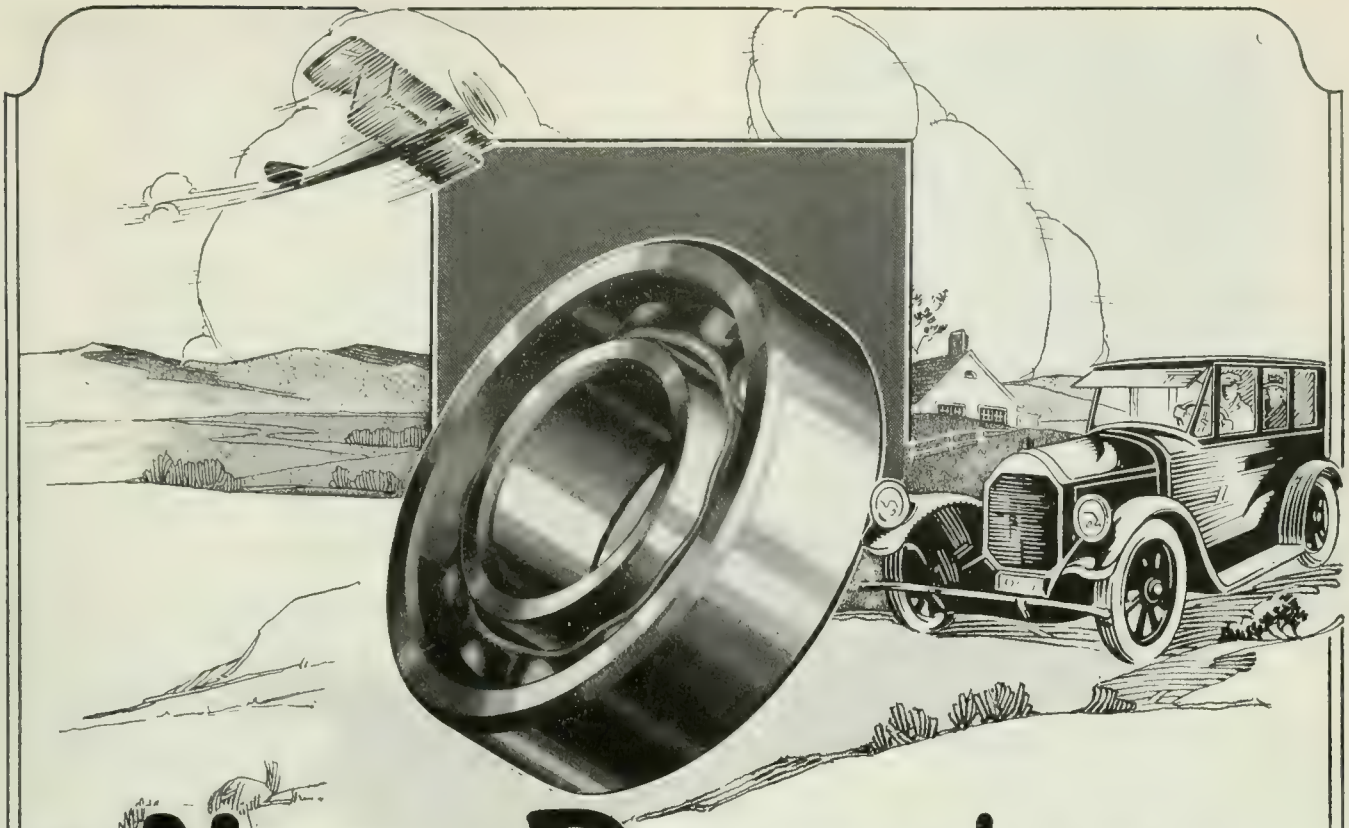
1310 Body Engineer; Graduate mechanical engineer with wide experience in high-grade custom body and quantity production, including closed and open bodies; also taxicabs; closed bodies preferred; acting in consulting capacity at present; highest references. Residence, Chicago; location, immaterial.

1311 Transportation Manager or Research Engineer in tractor factory; several years' experience as instructor and production engineer. Residence, Chicago; location, Middle West preferred, but not essential.

1312 Gage Engineer, Chief Inspector, executive, with unusual scientific and manufacturing experience covering 12 years, desires a position of responsibility. Has large engineering acquaintance from accomplishments, technical writings and personal contact. Residence, New England; location, immaterial.

(*Continued on p.* 78)

See announcement at the head of the S. A. E. Employment Service column, p. 68.



New Departure Ball Bearings

New Departures Simplify Maintenance

More than ever, motor vehicles are bought with an eye to the probable upkeep expense. Because they know that the labor to "get at" a part is often more than the cost of that new part, buyers are willing to pay more for a car or truck whose parts are known to have long life.

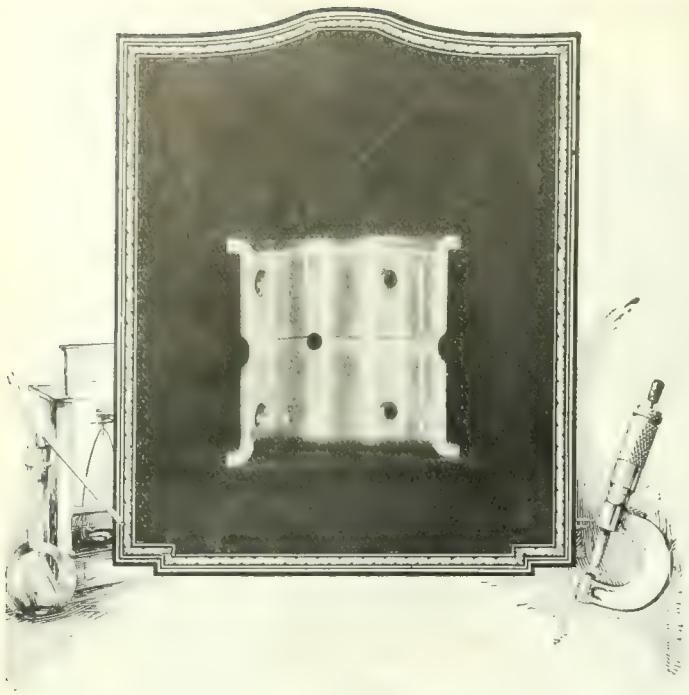
This also applies, in proportion, to parts which must be adjusted.

New Departure ball bearings last as long as the vehicle itself, for three reasons—correct principle, finest bearing steels, exquisite accuracy of dimension and finish. And this long life eliminates the necessity for adjustability.

THE NEW DEPARTURE MANUFACTURING CO.

BRISTOL, CONN.

CHICAGO **DETROIT**



Exactly to Specifications

The buyer of Hoyt Babbitt-Lined Bearings has the positive assurance that the finished product will be exactly to his specifications. If he orders S. A. E. No. 11 babbitt, he will get exactly that—if he orders bronze or babbitt to his own particular specifications he will get precisely the composition that he specifies.

Used by Prominent Motor Builders

Hoyt Babbitt-Lined Bearings are used by some of the foremost motor builders in the United States—they know that Hoyt bearings go far toward maintaining a reputation for uniform reliability of their product throughout a period of unusually long service. Send for 24-page book on Babbitt-lined Bronze Bearings.

HOYT METAL COMPANY

Boatmen's Bank Bldg., St. Louis, Mo.

New York **Chicago** **Detroit** **Toronto** **London**

Other Hoyt Products

Bronze-backed Babbitt-lined Bearings and Bushings
All-bronze Bushings
Stick Bronze, Cored or Solid.
Brass and Aluminum Castings.
Rolling Mill Bearings.
Babbitt Metals.
Die Castings of Zinc Base, Tin Base and Special Alloys.
Sheet Block Tin.
Lead Pipe.
Lead Pipe.
Special Casting Metals.
Sheet Lead
Lead Washers.
Tape Lead
Lead Sleeves.
Lead Wood
Lead Wire
White Copper Stamping Metal.
Casting Metals.
Solder (bar and wire)

Established 1873

HOYT

Bronze-Backed Bearings

S. A. E. EMPLOYMENT SERVICE

Continued

MEN AVAILABLE

1313 GENERAL SALES OR ADVERTISING MANAGER: graduate electrical engineer who has taken post-graduate work in business administration and has a successful record in the sale and advertising of several mechanical products; can take charge of established products or develop new ones for manufacturers or dealers and render valuable assistance in perfecting design and standardizing products; handles men successfully and coordinates inter-departmental relations. Available July 1. Residence, Ohio; location, Los Angeles or New York City preferred.

1318 CHIEF ENGINEER, WORKS MANAGER, PRODUCTION OR TECHNICAL SERVICE ENGINEER Traveling road man with experience in design, experimental work, pattern shop and inspection department wishes to get into production work or engineering and production combined. Residence, Indiana; location, immaterial.

1319 PRODUCTION ENGINEER, WORKS MANAGER; 6 years' experience in woodworking and rubber industries. Residence, Philadelphia; location, East preferred.

1320 SUPERINTENDENT; in charge of fleet of 60 commercial and light automobiles for passenger and haulage service, including Pierce-Arrow, Peerless, Albions, etc.; has also worked in machine, fitting and body shops and power station. Residence, England; location, immaterial.

1322 DETAIL DRAFTSMAN; available now; 3 years' experience and 2 years' technical training. Residence, Illinois; location, immaterial.

1323 EXPORT MANAGER, EXECUTIVE; 15 years' experience with prominent companies and several years as sales manager for Eastern territories; speaks five languages fluently and has traveled all over the world; best of references. Residence, Germany; location, immaterial.

1324 MECHANICAL ENGINEER; technical graduate with experience in shop, toolroom, inspection, tool design and development and aviation engines: airplane work a specialty. Residence, New York City suburb; location, New York vicinity preferred but not essential.

1327 EXPERIMENTAL ENGINEER, INSPECTION MAN; 15 years' engineering experience including field research inspection. Residence, Utah; location, West preferred.

1328 CHIEF OR DESIGNING ENGINEER; 14 years' experience in the design of air-cooled engines, complete cars and all units, including 5 years in office of chief engineer. Residence, Ohio; location, Ohio or farther East.

1329 SERVICE MANAGER Capable aggressive executive who possesses the ability to organize an effective department and has made an intensive study of all phases of passenger and truck service problems, and has been associated with two of the leading automobile companies. College graduate. Residence, Cleveland; location, immaterial.

1330 FACTORY MANAGER, CHIEF ENGINEER Man who is now with one of the largest passenger-car builders in the East desires to make a connection of similar capacity in Ohio, Indiana or Michigan with well-established firm. Available at an early date. Residence, Ohio.

1332 METALLURGICAL ENGINEER; technical graduate with 6 years' experience and a practical and theoretical knowledge of heat-treatment and metallography of all ferrous and nonferrous alloys, also nonferrous foundry practice; capable of directing metallurgical laboratory, heat-treatment department or foundry; expert on pyrometry.

1333 WORKS MANAGER, OPERATING ENGINEER OR TECHNICAL REPRESENTATIVE; 17 years' automotive experience in the design and production of cars, commercial and battery vehicles and a production knowledge of Entz magnetic system; also lecturing experience; would represent leading American company in England; otherwise open to position in United States. Residence, London.

(*Continued on p. 80*)

See announcement at the head of the S. A. E. Employment Service column, p. 68.

TRANSMISSIONS

Unit Power
and
Main Frame

CLUTCHES

Multiple Disc
and
Multiple Lever, Single Plate

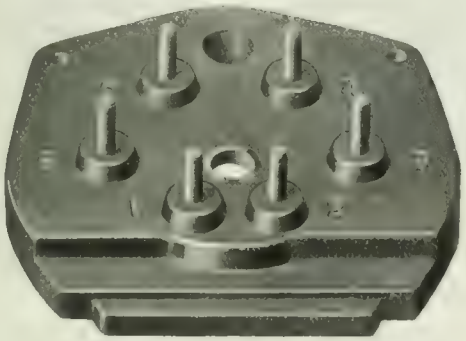
CONTROLS

A Style and Capacity
for
Every Requirement

BROWN-LIPE GEAR CO.

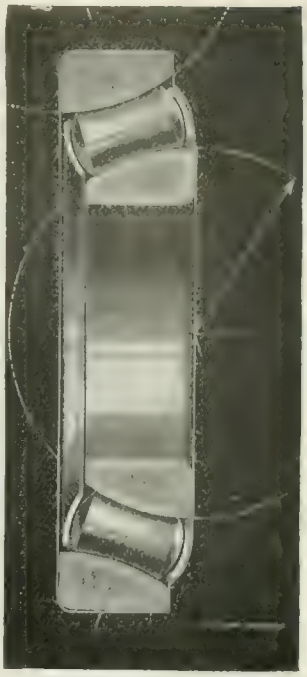
SYRACUSE, N. Y.

San Francisco Chicago Detroit
New York London, Eng.



The new plant of the International Insulating Corporation, now located at Elyria, Ohio, has been completed and is in production on gear shift lever balls, distributor heads, radiator caps, electrical connections, and all moulded parts, either from shellac composition or synthetic material, used on automobiles.

INTERNATIONAL INSULATING CORPORATION
ELYRIA - - OHIO



(Pat. and Pat. Pending)

Shafer Roller Bearing is Self-Aligning

The inner cone, being a true sphere, is free to tilt in all directions, making it automatically self-aligning.

It is an original combination of mechanical principles, having concave rollers set at an angle, traveling between a convex cup and cone. This construction makes it possible to absorb loads from any angle, either radial or thrust without pinching or binding.

Shafer Engineers Are At Your Service.

SHAFER BEARING CORP.
6501-99 West Grand Ave., Chicago, Ill.

SHAFER
Self-Aligning ROLLER BEARING

SERVICE FLOOD OILING FAN

"If It's a Flood Oiling Fan, It's a Service Fan"

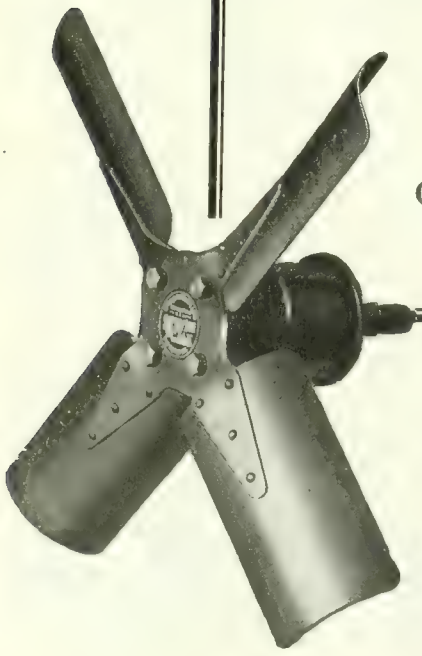
Quiet operation after almost unbelievable mileage is the result of the flood oiled plain bearing which is a feature of Service Fans.

Thousands of miles can elapse before it is necessary to replenish the oil supply.

Service Fans have demonstrated their superiority on motor cars, trucks and tractors.

Technical data will be supplied on request.

Service Products Corporation
Indianapolis
Indiana



Put Your Cooling Problems Up to Us

S. A. E. EMPLOYMENT SERVICE
Continued

MEN AVAILABLE

1334 AERONAUTICAL LAYOUT ENGINEER Technical graduate with 6 years' experience designing aircraft, including bombers and smaller metal construction, and recently in charge of body design including supervision of construction. Residence, Cleveland.

1338 RESEARCH AND DESIGNING ENGINEER; technically educated man in both mechanical and electrical lines who understands production methods thoroughly; can furnish best of references on sleeve and poppet-valve engines and chassis construction. Residence, New York City; location, New York City preferred.

1339 CHIEF ENGINEER, FACTORY MANAGER; thoroughly familiar with all engineering problems and factory management in the automotive industry; references available; now in Texas. Residence, Long Island; Eastern location preferred, but will go anywhere if inducement is sufficient.

1340 AUTOMOBILE FACTORY SUPERINTENDENT, WORKS MANAGER. Good executive with extensive experience in the assembling, body building, painting, trimming, enamelling and machine divisions wishes a position with a future. Residence, Canada; location, immaterial.

1343 EXECUTIVE ENGINEER; with 18 years' experience and who has held positions of assistant to president and chief engineer of some of the largest companies in the engineering field, and shown results that are recognized throughout the entire industry, would like to hear from high-grade organizations requiring his services, exceptional references; also European experience in accessories. Residence, New York; location, New York City preferred but not essential.

1344 RESEARCH AND DEVELOPMENT ENGINEER; extensive experience in developing new products and perfecting improvements in older ones; thoroughly competent in research technique and possessing resourceful engineering ability; automotive and oil engine work a specialty. Residence, Pennsylvania; location, Philadelphia or Metropolitan district.

1345 SERVICE MANAGER; 4 years' experience in passenger-car and truck service and sales; 8 years' cost and production; 4 years' export sales and service and 8 years' building passenger cars and trucks. Residence, Long Island; location, New York City preferred, but not essential.

1346 RESEARCH ENGINEER; 17 years' experience as foreman, chief inspector, passenger-car and truck testing; research engineer in passenger-car and truck design; can organize personnel; now employed. Residence, Indianapolis; location, Central States preferred.

1349 DESIGNING AND RESEARCH ENGINEER; graduate of European technical university who speaks English, French, German and Dutch; expert airplane-engine designer. Residence, Connecticut; location, immaterial.

1354 MECHANICAL ENGINEER; builder of high-class automobiles; development and research work; has had charge of assembly department of prominent automobile company. Address, J. Kaufman-Kawst, c/o S. A. E., 29 West 39th St., New York City

1355 TECHNICAL GRADUATE; age 24; with experimental laboratory and practical experience and a well-established knowledge of internal-combustion engine characteristics. Available in June. Residence, Kansas; location, immaterial.

POSITIONS AVAILABLE

544 SALESMAN wanted by a die-casting company in Pennsylvania.

545 ASSISTANT SALESMAN. Capable man is desired by a prominent company in Pennsylvania manufacturing aluminum, brass and bronze die castings.

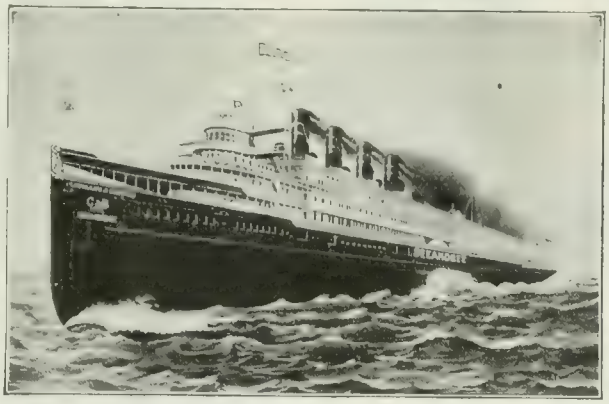
(*Continued on p.* 82)

See announcement at the head of the S. A. E. Employment Service column, p. 68.

Make Your Trip to Spring Lake More Enjoyable by a Refreshing Night on Lake Erie

Thousands of eastbound travelers say they wouldn't have missed that cool, comfortable night on one of our fine steamers. A good bed in a clean stateroom, a long, sound sleep and an appetizing breakfast in the morning! (And your car arrives on same steamer.)

C&B LINE



C&B LINE

The Great Ship "SEEANDBEE" and Steamers "City of Erie" and "City of Buffalo"

Daily, May 1 to November 15.

Leave Cleveland..... 9:00 p.m. Leave Buffalo..... 9:00 p.m.
Arrive Buffalo..... 7:30 a.m. Arrive Cleveland..... 7:30 a.m.
(Eastern Standard Time)

Fare: $5.50 One Way; $9.50 Round Trip

Tourist Automobile Rates (When accompanied by passengers)

	One way.	*Round trip.*
Cars 127 inches wheelbase or less.....	$10.00	$15.00
Cars over 127 inches wheelbase.....	14.50	24.00

All gasoline must be removed before cars can be accepted for shipment. Cars should be delivered to dock one hour prior to departure of steamer.

(Your rail ticket is good on the boats.)

THE CLEVELAND AND BUFFALO TRANSIT COMPANY

Cleveland, Ohio.
City office, 2051-3 E. 9th St.,
New Pier, ft. of E. 9th St.

Buffalo, N. Y.
City office, 16 E. Eagle St.,
Wharves, S. Michigan Ave. Bridge.

DAHLSTROM
Metal Mouldings & Shapes

DURABLE—ARTISTIC
Metal Instrument Panels

Dahlstrom metal instrument panels will not twist or warp. They are easily applied, and instrument openings are neat and carefully made.

Dahlstrom instrument panels are finished by our baked-on process in any color or graining desired.

DAHLSTROM METALLIC DOOR COMPANY

467 Buffalo Street, Jamestown, New York

PHILADELPHIA 305 Bulletin Bldg. DETROIT 501 Capitol Theatre Bldg. CHICAGO 19 So. LaSalle St.

Local representatives in principal cities.

The Highest Development of Vulcanized Cotton Fibre

IT has taken nearly a half a century to produce Vul-Cot Fibre—a half century of study and experiment to produce material of exceeding toughness and hardness and that is not brittle.

Vul-Cot is made by the oldest and largest manufacturer of Vulcanized Fibre in the country. Every detail, every process in the manufacturing of Vul-Cot Fibre is performed in the three huge plants of the National Vulcanized Fibre Company.

The result is a Fibre that is three times as tough as leather. No ordinary force can crush, break, crack or split it. Its tensile strength is from 9,000 to 14,000 pounds per square inch, with a resistance to shearing up to 13,000 pounds per square inch, and an electrical rupture up to 400 volts per Mil.

We have made Vul-Cot Fibre with such care, with such minute attention to every detail, that we can guarantee it to be free from impurities.

If there is a place for fibre in the composition of your product—if there is a possibility for a material that is as hard as horn, as durable as steel, as adaptable as rubber and yet less costly than any—we will gladly place at your disposal the experience gained through years of making parts for the products of the host of manufacturers who use Vul-Cot Fibre.

National
Vulcanized Fibre Company
Wilmington, Delaware

S. A. E. Employment Service

Continued

POSITIONS AVAILABLE

*575 Carbureter Sales Engineers to call on factories, make demonstrations, etc., are desired by old established factory in Middle West. Must be experienced, have technical training and good references.

*577 Sales Engineer for ball bearing company. Must be thoroughly familiar with the automotive field. Ball bearing experience desirable but not required. Practical experience is necessary.

578 Engineer with sales experience and who has a wide acquaintance among engine companies or automobile plants that build their own engines; an acquaintance not only with the purchasing departments but with the engineering departments. Necessary to travel extensively, selling internal-combustion engine valves or other parts that this company makes, such as tappets, etc. Not necessary to make the actual sales because it will be necessary for him to devote himself particularly to the engineering requirements of customers, coming in contact with purchasing departments in an incidental way. Man must be capable of earning good salary and will work under the direction of the chief engineer. Location, Detroit, and traveling will take in entire territory from Minneapolis to New York City.

589 Salesman. Company in Ohio is interested in obtaining a salesman for its industrial bearings division work, covering the sale of its product to industries outside the automotive field where anti-friction bearings are adaptable. This work requires a man with engineering training, as contact is generally with engineers, and sales experience. Prefer a man of about 30 to 35 years of age and single, as the work requires considerable traveling; pleasing personality and plenty of energy are also essential. A man is desired who will appreciate the opportunity of a position with a prominent organization and who will be keenly interested in the work at hand.

590 Implement Designer and Factory Manager. Man able to combine the qualities of both is wanted by plant in Ohio.

*602 Experienced Sales Engineer to cover large territory and call on automobile builders that this company represents. A certain amount of engineering and technical detail is required. Prefer a single man with sales ability and technical knowledge. Salary, from $2,500 to $3,500, according to qualifications, experience and earning power. Write, giving education, experience, salary, etc. Headquarters, Detroit.

*605 Man to take charge of the inspection work of plant, located in New York City and manufacturing piston castings. Enough technical education at least to enable him to understand technical details and enough practical experience in manufacturing lines so as to be familiar in a general way with shop practice are required. Applicants should be familiar with testing machines and equipment, such as Brinell hardness tester, tensile test machine, pyrometer equipment, etc., and be able to use this equipment intelligently; it is also desirable that they understand the operation of gas and oil furnaces; be able to devise and make reports covering work tested as well as to observe work in process through the shop and make such reports as may be required; be competent to take and understand instructions fully, and to follow them out cheerfully. Preferably bright young chap who can stand on his own responsibilities under supervision. Write details fully. Wanted immediately.

607 Automotive Design Engineer. Duties cover original study and engineering work on automotive material, particularly the development of tracklaying and combined wheel and tracklaying mechanisms. Position requires the services of a high-grade man who is able not only to make layout studies on the board, but also to transmit the work to the staff and layout draftsmen for completion of the design. A man of special attainment based upon several years' experience in character of work described is what is desired. Salary, $5,000 for right man; location, Illinois.

(*Continued on p. 84*)

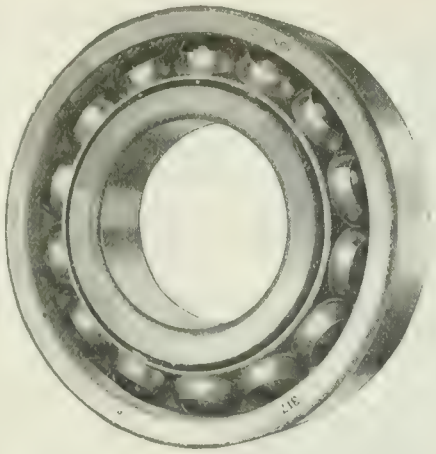
See announcement at the head of the S. A. E. Employment Service column, p. 68.

HOOVER

The Worlds Largest Ball Plant

STEEL
BRASS
BRONZE
MONEL METAL
BELL METAL
ALUMINUM
AND HOLLOW BALLS

HOOVER STEEL BALL CO
ANN ARBOR, MICH.



Higher Overload Capacity

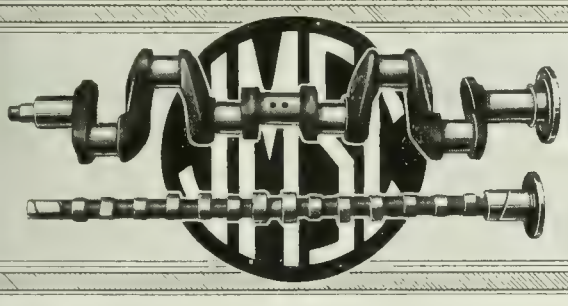
BY virtue of their use of the greatest possible number of largest possible size balls, Gurney Bearings withstand shocks and overloads that would be disastrous to other bearings.

Their remarkable accuracy and uniformity of manufacture—and the fact that their load capacity is greater than other bearings of equal size,—makes Gurneys best suited for replacement work. Their use adds a stronger part to the machine.

If you design machines, our Engineers can help you—will you let them?

Gurney Ball Bearing Co.
Conrad Patent Licensee
Jamestown, N. Y.

GURNEY
BALL BEARINGS



The Largest Manufacturer Finishing Both Crankshafts And Camshafts Exclusively

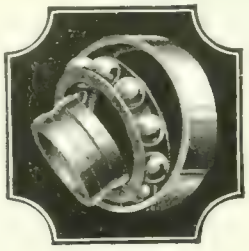
200,000

motors built annually for passenger cars, tractors and trucks are timed by our camshafts and driven by our crankshafts.

Mr. Motor Builder, our experience and facilities merit your consideration.

JACKSON MOTOR SHAFT COMPANY
JACKSON - - - MICHIGAN

"NORMA"
PRECISION
BALL BEARINGS



For Lighting Generators and Ignition Apparatus

The owner of a car or truck—if it fails—notes only the bare fact of failure. Seldom does he seek the ultimate source of trouble. He condemns the machine as a whole—and a subsequent sale is lost.

The builder of a car or truck condemned because of ignition or lighting generator trouble places the blame where it belongs. And the sale, not of one equipment but of hundreds, may be lost to the builder of the electrical apparatus.

Service records prove that magnetos and lighting generators equipped with "NORMA" Precision Bearings, run more quietly, last longer.

A booklet will be sent on request. And our engineers will welcome an opportunity to work with yours.

THE NORMA COMPANY OF AMERICA
Anable Avenue
Long Island City New York
BALL, ROLLER AND THRUST BEARINGS

S. A. E. Employment Service

Continued

POSITIONS AVAILABLE

*611 Production Manager. High-grade factory executive with experience in die-making, foundry, and non-ferrous metals and able to handle men. Location, New York City.

612 Electrical Engineer. A live wire with experience in the repair and maintenance of automotive electrical equipment, who is or could be trained for field service, a man with "pep" who would be able to act on his own initiative is desired. Location, Springfield, Mass.

*613 Steel-Treating Foreman to direct production and maintain equipment. Must be able to handle men and be experienced in present methods. Average output of department six tons per day including carburizing and alloy and carbon steels. Location, California.

616 Salesman is needed by a company about to start a merchandising campaign on a carbureter to take complete charge of the enterprise. Device is fully developed, has had extended commercial service locally and has many advantages. [Man should have sound merchandising training; be rather well-known in the industry; technically trained at least in a general way, expert engineering talent is now employed by this company; and have actual experience in selling to the replacement market a product handled through same channels as a carbureter. If he has had this type of experience in the carbureter business, so much the better. Factory equipment solicitation also part of the duties. An interest in the company and compensation in proportion to the results obtained will be offered with a base salary sufficient to preserve a decent standard of living until such results begin to show. Location, Pennsylvania.

622 Engineer; preferably a young man just out of college is wanted immediately for general engineering work, including material testing. Location, suburb of New York City.

*627 Research Man is desired by a prominent company in Connecticut.

*628 Car Tester. Good first-class man is wanted to take charge of rough and finished testing, should be a thorough mechanic and well acquainted with what a high-grade car ought to be, possess a keen mind for analyzing trouble and be a good executive, not white collar man, but one willing to get down to work. Location, Connecticut.

630 General Factory Superintendent for plant whose production is on hose clamps, spark-plugs, automobile pumps, etc., and employs about 60 people, male and female. Equipment consists of automatic screw machines, presses, assembling, etc. Will pay salary with bonus on business to a suitable man possessing a wide experience and capable of producing results.

631 Engine Designers are wanted immediately by an aircraft company in New Jersey for permanent position. Not necessary that applicants have had airplane experience, but preferable. Salary, around $50 per week, or dependent upon the man.

*634 Body Engineer. A permanent position with a reliable organization is open to a high-grade man who is thoroughly familiar with all classes of materials used in body construction, their sources, methods of manufacture and application in body work. He must also be familiar with the production of the bodies themselves and all their component parts, including painting and trimming. Location, Detroit.

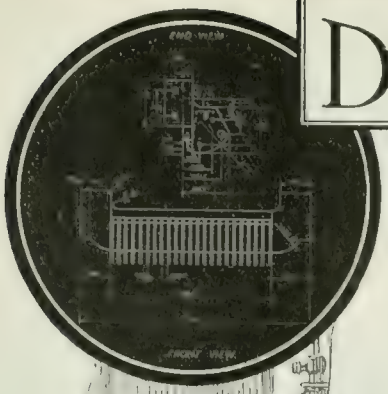
*635 Young Sales Engineer with a wide acquaintance among manufacturers. Headquarters, Detroit. Territory, State of Michigan. Salary, commensurate with ability, ranging from $2,500 to $4,000 per year.

*636 Body Engineer with wide experience, who is thoroughly capable and diplomatic and possesses a pleasing personality, to take charge of men in a Connecticut factory

(*Concluded on p. 86*)

See announcement at the head of the S. A. E. Employment Service column, p. 68.

FRANKLIN DIE-CASTINGS



The Direct Way to RESULTS

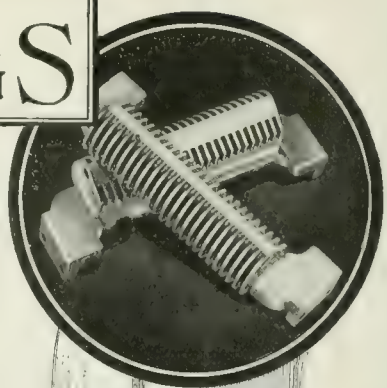
We once asked the manufacturer for whom we make this part, "How much did it cost you before you decided to have it die-cast?" He replied, "We never tried to make it any other way."

It could have been built up from a series of stampings mounted on the machine base, but Franklin Die-Castings were a direct way to the results desired, and our customer was wise enough to see it.

This is only one case where the designer, by specifying die-castings, has made a substantial saving possible at the outset.

We originated the Die-Casting Process in 1892, and for 30 years have been reducing costs and simplifying output in many fields of industry.

Let us solve your die-casting problems. We quote from samples or blue-prints. Write for booklet: "Franklin Die-Castings in Modern Inventions."



FRANKLIN DIE-CASTING CORP.
Gifford and Magnolia Streets
Syracuse, N. Y.

To Insure Your Car Upholstery Against Wear, Use

"Wire on" Moulding

A combination of Beauty, Refinement and Stability.

WIRE ON is being successfully used in the trimming of tops and open and closed bodies, both pleasure car and bus.

WIRE ON is made with coverings of genuine leather, artificial leather, and cloth. It is easily and successfully applied on any job.

We have been making Mouldings, Gimps, Welts, Robe Rails, Straps and other Automobile Trimmings for many years.

Samples sent upon request.

The George R. Carter Company

Connersville, Indiana

OWEN Dyneto CORPORATION

Owen-Dyneto Corporation
Syracuse, N. Y.

Manufacturers of High Quality

Starting and Lighting Equipment for the Automotive Industry

Simplicity of Design
All Parts Accessible
Exceptionally Efficient

Service Stations in All Principal Cities and Towns

S. A. E. EMPLOYMENT SERVICE

Concluded

POSITIONS AVAILABLE

637 DRAFTSMEN for automobile work with automobile experience and an acquaintance with S. A. E. Standards are wanted immediately. Preference will be given to men now located in the East. Salary, $30-$45 per week. Location, Massachusetts.

*638 MAN, 30-40 years of age, possessing the ability to write technical articles and lecture, is desired for an executive engineering position. One having had practical automotive engineering experience will be preferred. College education is desirable but not essential. Location, New York City.

639 AUTOMOTIVE ENGINEERS, two or three first-class men, experienced in layout work, tool-designing and transmission, are wanted by company in New Jersey. Salary, $50-$55 per week.

640 SALES ENGINEER on gear cutting and gear tooth-grinding machinery is wanted for Eastern territory with headquarters in New York City. Salary, $200 per month and expenses plus commission. Men in other territories making $5,000 to $8,000 per year on same basis.

641 YOUNG SALES EXECUTIVE to take charge of sales of a growing motor-truck company. Must be capable of compiling sales manuals, formulating sales policies, building up sales organization and supervising advertising. Man of integrity and ability, willing to start with a small salary, is desired. Position offers an opportunity to get in on ground floor with a young organization and build a future. Replies will be held strictly confidential. Location, Ohio.

642 SALES ENGINEER is wanted by a company operating in the States of New York and New Jersey to distribute engineering specialties. Good opportunity for a hustler. Headquarters, New York City.

643 DRAFTSMAN wanted for detail layout work. Salary, around $40 per week. Location, New York City suburb.

644 DESIGNING ENGINEER, who is qualified to design and layout tractor engines and transmissions for quantity production, is wanted by large tractor factory located in California. Only applications from men of broad experience along tractor or other automotive lines will be considered.

645 TECHNICAL GRADUATE, just out of college, is desired immediately to handle testing on aircraft engines. Must be able to conduct tests, write reports and make performance calculations. Airplane experience desirable but not essential. Salary, around $30-$35 per week. Location, New Jersey.

646 CHASSIS LAYOUT DRAFTSMEN Chicago company is in urgent need of several first class men.

647 ENGINE DESIGNERS One or two men with experience are wanted immediately by company in Chicago.

648 PETROLEUM ENGINEER; salary, $3,000-$4,000 per year. Associate petroleum engineer; salary, $2,200-$3,000 per year. Assistant petroleum engineer; salary, $1,800-$2,200 per year. Applications rated as received until further notice. Apply to United States Civil Service Commission, City of Washington, for Form 2118.

649 LAYOUT DRAFTSMAN Fast worker, preferably with some experience on engine work, is wanted by an airplane company in New Jersey.

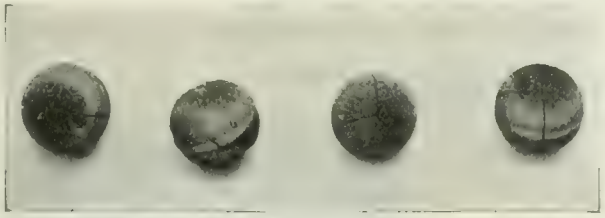
*650 ENGINEER, skilled in sheet metal stamping, drawing and die work; must have both technical and practical knowledge and be capable of designing and supervising the design of dies for small and medium size metal stampings, some of which will be of a very complicated character. Location, Michigan.

*651 ENGINEER to take charge of research laboratory located at Cleveland and conduct engine tests.

652 DRAFTSMAN-DESIGNERS are wanted immediately for work in New York City. Preference will be given to men from the vicinity of New York City who are experienced in automotive work and general machine design. Salary depends on the man.

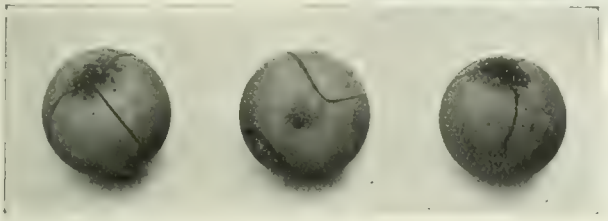
See announcement at the head of the S. A. E. Employment Service column, p. 68.

Fafnir Turned Balls deeply etched in hot hydrochloric acid No sign of cracks



Cold Headed Balls (not Fafnir) deeply etched in hot hydrochloric acid. Note cracks revealed. All of these balls had been passed by inspectors

Hot Forged Balls (not Fafnir) deeply etched in hot hydrochloric acid. Note cracks revealed. All of these balls had been passed by inspectors.



The Bearing User Wants UNIFORM Ball Bearings, Not Two or More Poor Ones Out of Every Hundred

Our investigation has shown that in the past the balls have invariably been the weakest part of the bearing. Consequently we have directed our energies to the development of better balls. As the result, we have found turned balls to be far superior to all others.

One has only to glance at the above photographs to see that the profound mechanical deformation which the steel suffers in cold heading or hot forging balls causes severe initial internal strains and stresses which are liable to produce cracks that will cause premature fatigue and failure when the balls are placed in service.

When balls are turned, on the other hand, the normal condition of the steel is perfectly preserved and consequently there is no danger of fatigue.

The "Dragon" for June tells the whole story. Ask us to send you a copy.

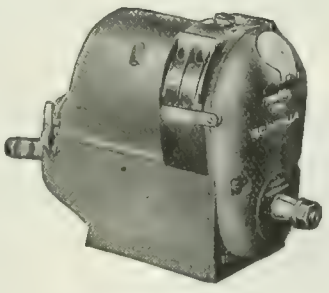
The Fafnir Bearing Company
Conrad Patent Licensee
New Britain, Conn.

CHICAGO, ILL. 537 South Dearborn St.
DETROIT, MICH. 120 Madison Ave., Room 511
CLEVELAND, OHIO. 1016 1017 Swetland Bldg.
NEW YORK, N. Y. 5 Columbus Circle
NEWARK, N. J. 271 Central Ave.
PHILADELPHIA, PA. 1427 Fairmont Ave.

What Is the Cost of Poor Ignition?

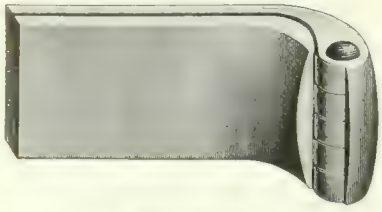
Usually the condemnation of the entire vehicle by its owner because of lost time and annoyance.

Scintilla ignition, by reason of its sound engineering design and splendid construction has proved its unfailing reliability in all classes of service. Witnessed by its universal success in automobile racing, aeronautics and by its choice as standard equipment by the most critical passenger car, truck manufacturers and fleet operators.



SCINTILLA MAGNETO CO., INC.
225 WEST 57th ST., NEW YORK

VEHICLE HARDWARE



No. 9503

Lamp Brackets

Hinges

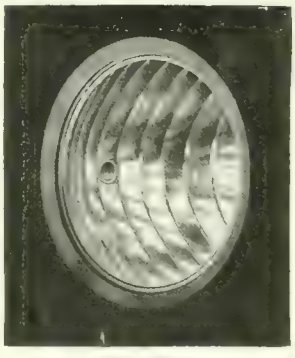
Hood Fasteners

No. 9507

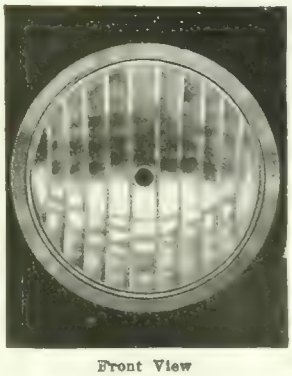
MALLEABLE IRON CASTINGS

THE EBERHARD MANUFACTURING CO.

CLEVELAND, OHIO



Side View
FLATLITE
All Light Directed Right



Front View

"All the Light—Directed Right"

FLATLITE REFLECTORS

assure perfect road illumination and are approved for use with clear glass lenses, in every state.

There Is No Glare

These scientifically constructed reflectors are figured with highly polished silvered parallel fluted stripes, so controlling the rays of light as to insure safety to driver and approaching car.

STANDARD EQUIPMENT ON CHANDLER, CHEVROLET, OLDSMOBILE, PAIGE, JEWETT and CLEVELAND.

Write Today for Complete Information

THE AMERICAN FLATLITE CO.

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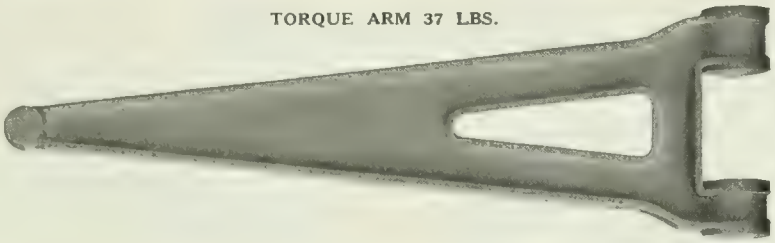

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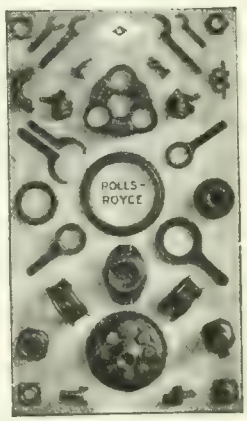

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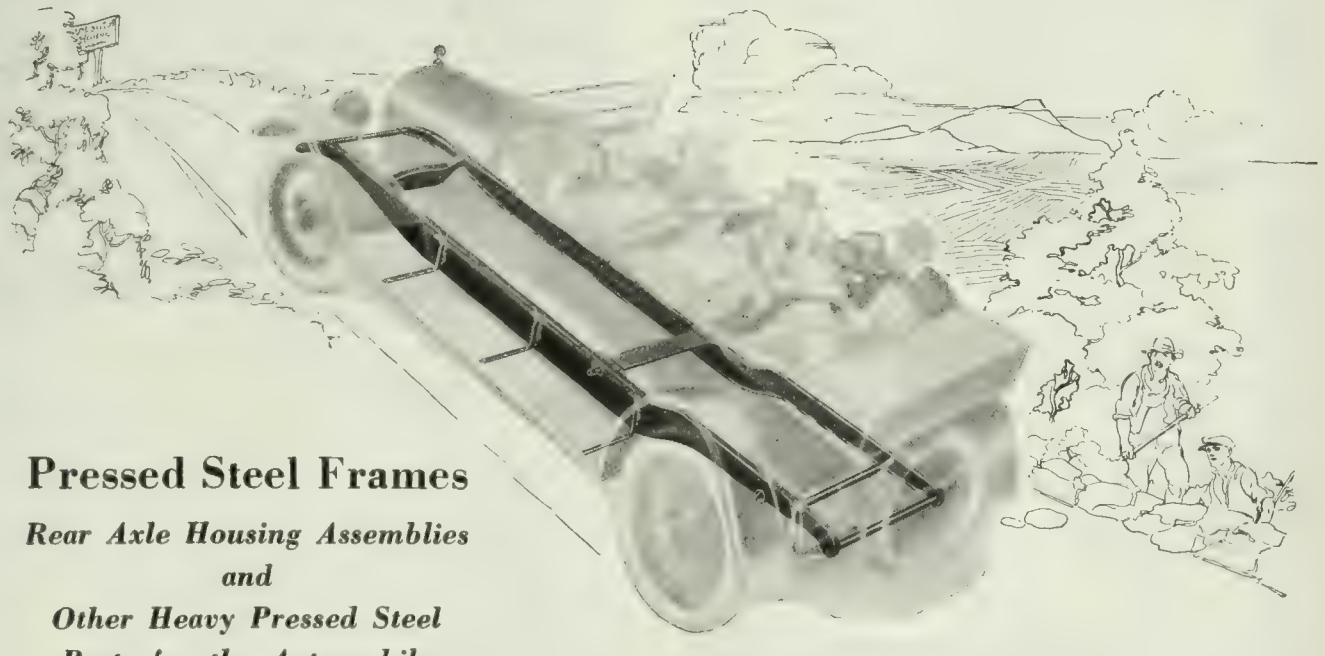

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You can overcome most metal troubles by sheer experience—trying out different mixtures, other tempers, changing tools, but—after all this trouble what assurance have you that you will not have to plow through this again the next time you tackle similar work?

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We can help you to determine *the correct metal* for the job and at the same time we can furnish it to you so that your production will not be interrupted by metal troubles.

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LIKE the far-famed illumination of the Great White Way of New York, brightly lighted motor busses advertise your service and attract patrons. There is no longer any question about the power of light to pull business. Night service by busses can be made as profitable as daylight operation.

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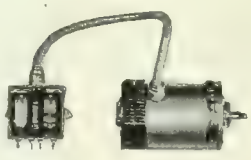

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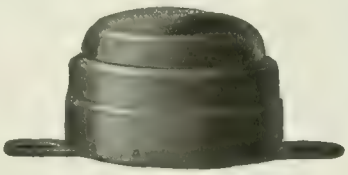

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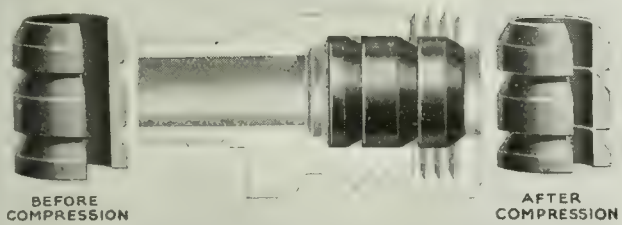

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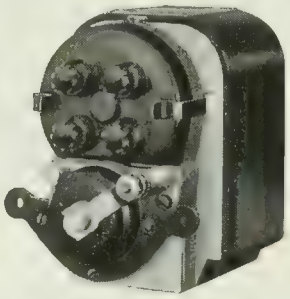

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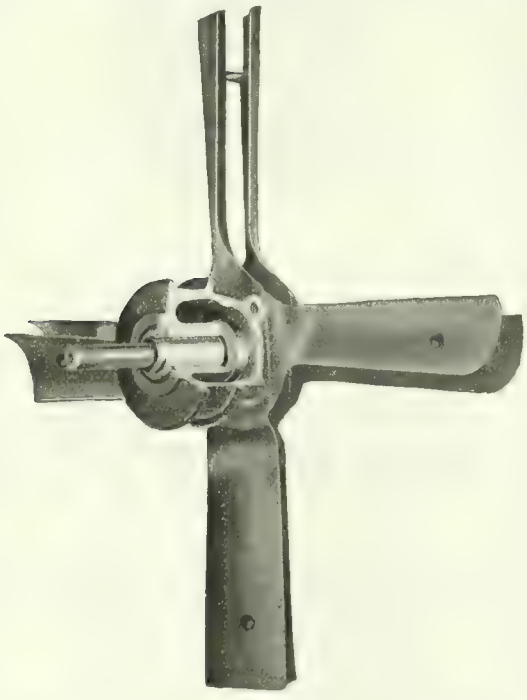

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SPRINGS

OF EVERY DESCRIPTION

SPRING FORMULAS

NOTATION

W = LOAD IN POUNDS
D = MEAN DIA. COIL (INCHES)
d = DIA. WIRE (ROUND) "
N = NUMBER OF COILS (ACTIVE)
G = TORSION MODULUS (11 500,000)
f = DEFLECTION (IN INCHES)
S = TORSIONAL STRESS

$$W = \frac{3.14\,S\,d^3}{8\,D}$$

$$W = \frac{f\,G\,d^4}{8\,N\,D^3}$$

In a spring with ends squared and ground N is the total number of coils minus 2.

Maximum stresses permissible vary with conditions—from a safe maximum of 40,000 for high speed engine valve work to as high as 110,000 for static loads and ordinary temperatures.

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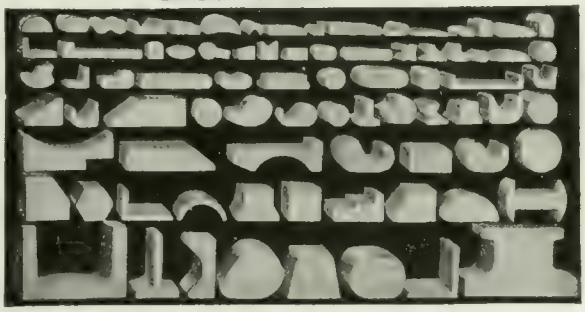

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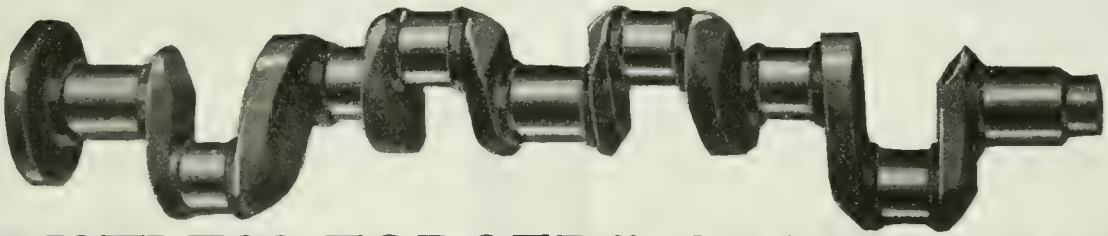

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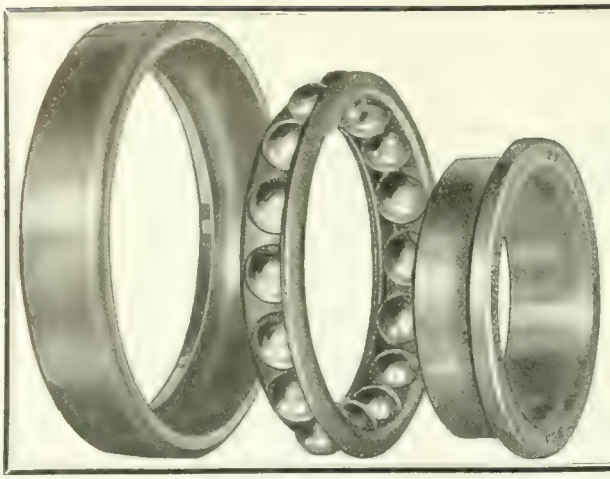

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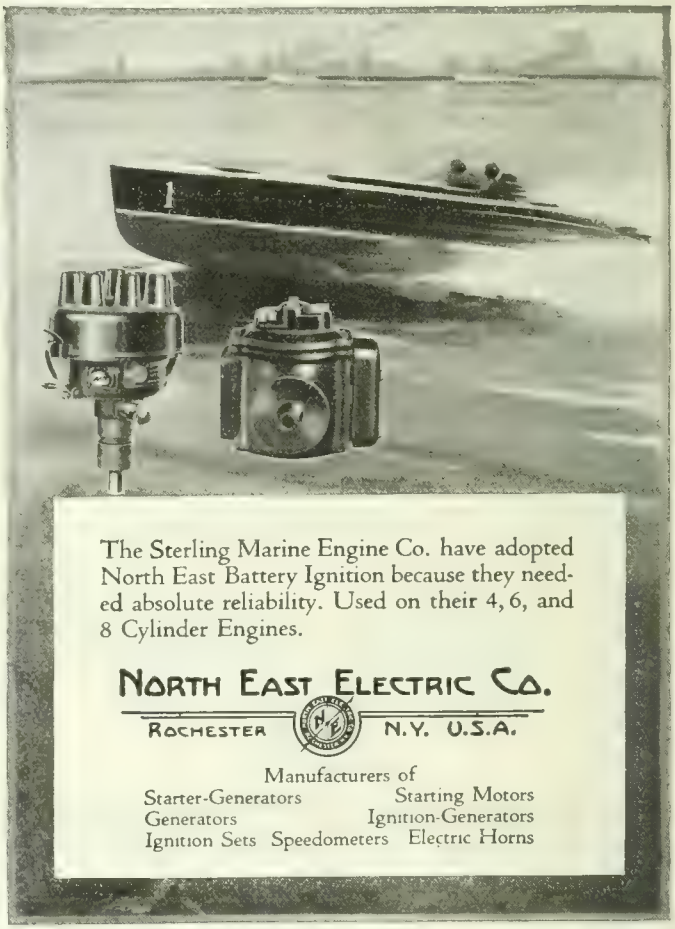

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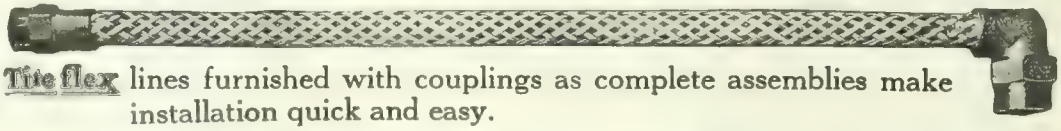

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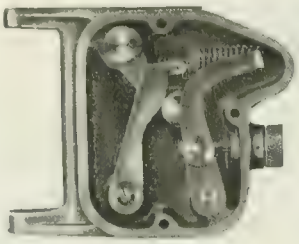

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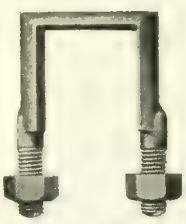

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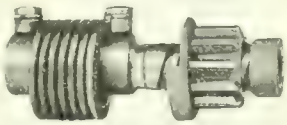

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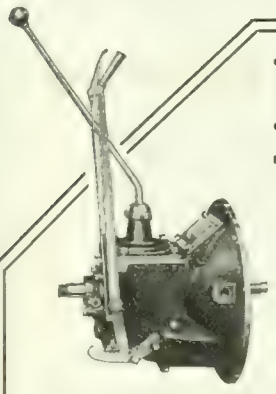

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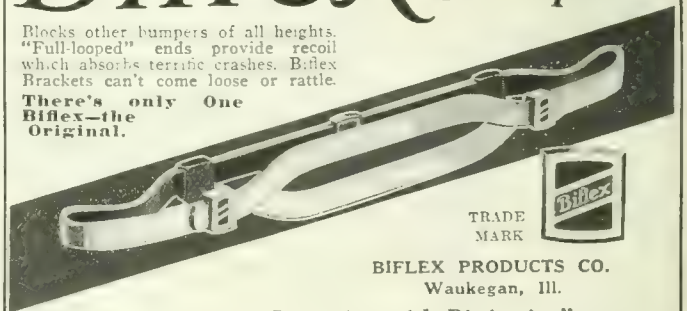

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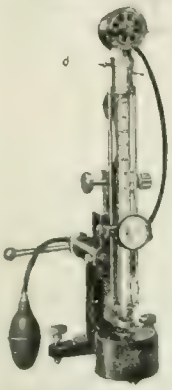

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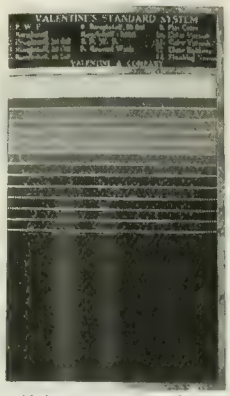

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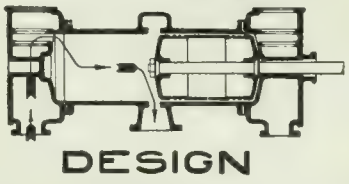

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(Continued on page 102)

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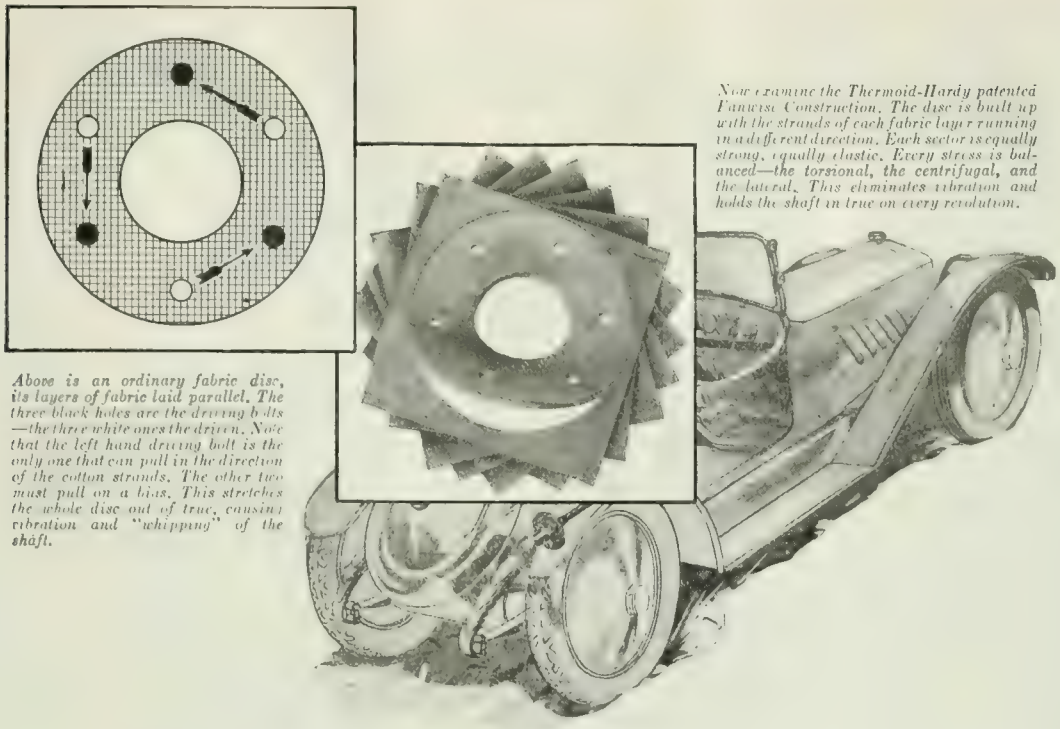
Parts and materials followed by key numbers have been standardized by the S. A. E. The numbers refer to S. A. E. HANDBOOK data sheets on which each standard is published.

*Companies whose names are preceded by an asterisk supply the parts or materials under which the company is listed as conforming with the S. A. E. Standard referred to.

**Parts and Materials followed by two asterisks indicate that two or more S. A. E. Standards are applicable. Information as to standards incorporated should be obtained from the manufacturer.

The addresses of companies listed in this index can be obtained from their current advertisements indexed on page 106.



Above is an ordinary fabric disc, its layers of fabric laid parallel. The three black holes are the driving bolts—the three white ones the driven. Note that the left hand driving bolt is the only one that can pull in the direction of the cotton strands. The other two must pull on a bias. This stretches the whole disc out of true, causing vibration and "whipping" of the shaft.

Now examine the Thermoid-Hardy patented Fanwise Construction. The disc is built up with the strands of each fabric layer running in a different direction. Each sector is equally strong, equally elastic. Every stress is balanced—the torsional, the centrifugal, and the lateral. This eliminates vibration and holds the shaft in true on every revolution.

Both fabric discs—*but the resemblance stops there*

Why one universal will stretch while the other holds shaft true on every revolution

When the flexible fabric disc first began to displace the metal universal, it had one big fault—it pulled out of true after a few thousand miles, causing vibration and "whipping" of the entire shaft.

Not until the famous Fanwise Construction of the Thermoid-Hardy disc was worked out did the fabric universal become a practical necessity.

The Thermoid-Hardy Joint was perfected to eliminate backlash and its accompanying troubles. Its flexible fabric discs cushion even the heaviest blows. It transmits a smooth, even flow of power instead of jolts and lost motion.

Examine the Thermoid-Hardy disc, with its patented Fanwise Construction. This disc is built up in layers, but the strands of each layer run in a *different direction*. The result is an even stress at every point—an equal strain between every pair of bolt holes.

Contrast this construction with that of the ordinary disc. Its layers of fabric are laid *parallel*. This means that only the left hand driving bolt can pull in the direction of the strands of cotton. The other two must pull *across*—on a bias. Stretching of the disc soon follows.

Fanwise Construction gives enormous strength

Fanwise Construction has added to elasticity a *rugged strength*. The Thermoid-Hardy universal withstands a torsional strain that twists a two-inch steel shaft—it is good for over 60,000 miles on a heavy truck, over *any* road, and without attention of any sort.

Thermoid-Hardy discs are now packaged for distribution through jobbers and dealers for replacement sales. Full information, prices, and discounts sent on request.

A book you should have

We have prepared a book, "Universal Joints—Their Use and Misuse," that treats the subject from every angle—the mechanical principles, construction, lubrication, manufacture, strength tests, and records of performance. Send for your copy today.

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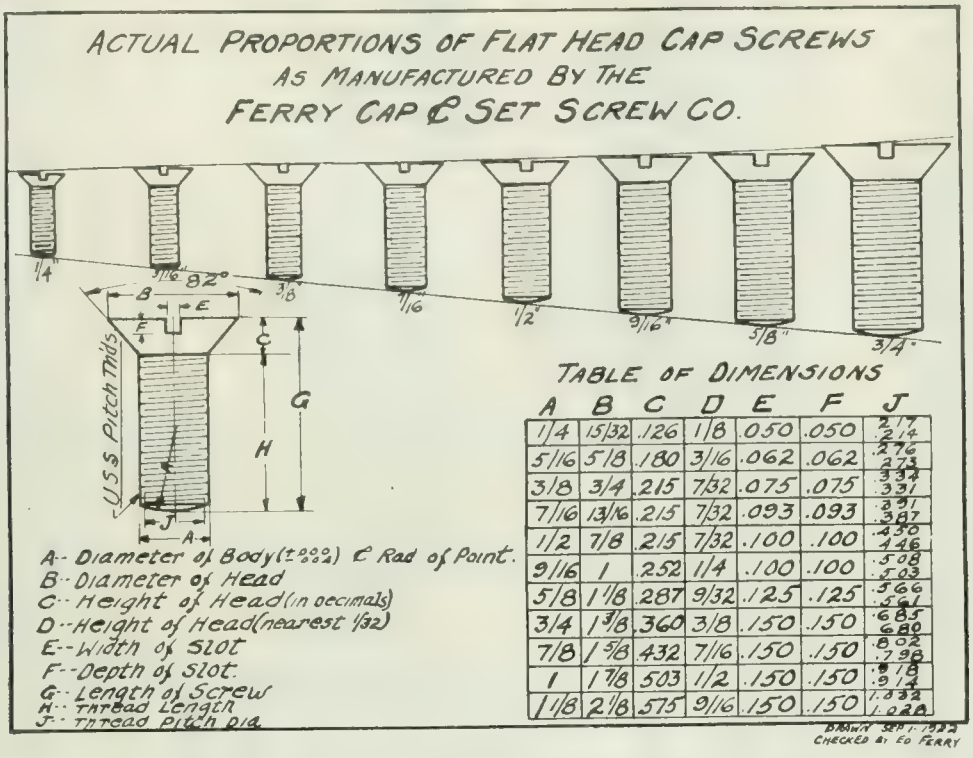
The Standard Screw


ACTUAL PROPORTIONS OF FLAT HEAD CAP SCREWS
AS MANUFACTURED BY THE
FERRY CAP & SET SCREW CO.
1/4
5/16
3/8
7/16
1/2
9/16
5/8
3/4
82°
B
E
F
C
G
H
J
A
U.S.S. Pitch Thds
A-- Diameter of Body (to 2nd) & Rad of Point.
B-- Diameter of Head
C-- Height of Head (in decimals)
D-- Height of Head (nearest 1/32)
E-- Width of Slot
F-- Depth of Slot.
G-- Length of Screw
H-- Thread Length
J-- Thread Pitch dia.
TABLE OF DIMENSIONS
A B C D E F J
1/4 15/32 .126 1/8 .050 .050 .214
5/16 5/8 .180 3/16 .062 .062 .276
3/8 3/4 .215 7/32 .075 .075 .334
7/16 13/16 .215 7/32 .093 .093 .391
1/2 7/8 .215 7/32 .100 .100 .450
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1 1 7/8 .503 1/2 .150 .150 .919
1 1/8 2 1/8 .575 9/16 .150 .150 1.032
DRAWN SEPT. 1922
CHECKED BY ED FERRY

Ferry Flat Head Steel Cap Screws

The same exacting care is used in the making of Ferry Flat Head Steel Cap Screws that is taken in the manufacture of all Ferry Process Screws.

Their uniform performance both in rugged strength and precision accuracy has been another great factor in building the reputation they now enjoy among careful buyers.

They are perfectly machined from top to bottom and accurately slotted so a screw driver will "stay put" no matter how great the pressure.

Reprints of this series of advertisements on Ferry Standard Screws will be sent upon request. Your Engineering, Drafting and Purchasing Departments should have them. Write today—

"If it's upset—it must be heat-treated."

THE FERRY CAP AND SET SCREW CO., Cleveland, Ohio

FERRY

PROCESS SCREWS

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How Do You Correct Your Connecting Rods?

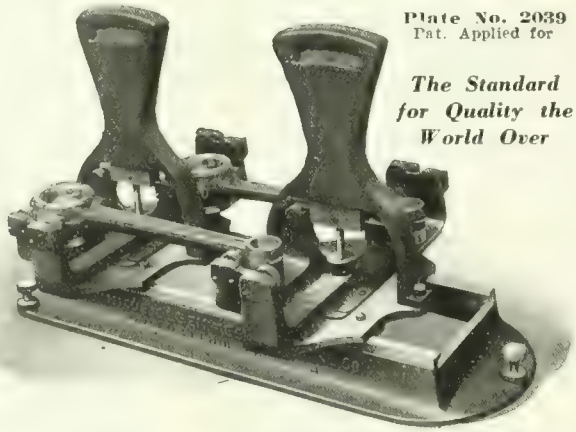

Plate No. 2039
Pat. Applied for

The Standard for Quality the World Over

All connecting rods should be corrected with reference to their total weight and location of center of gravity, i. e., each end must weigh the same and the sum total of the two ends the same.

The Olsen-Lundgren Automatic Weighing Connecting Rod Scale will at a glance and in a single operation, weigh such parts accurately and so that each and every connecting rod will weigh the same.

Standardize your connecting rods and reduce your costs by the Olsen-Lundgren method

OLSEN-CARWEN STATIC-DYNAMIC BALANCING MACHINES

Eliminate Vibration—Secure Perfect Balance with Speed and Economy

The Olsen-Carwen Machine is made in many sizes and types to balance any rotating parts from the smallest to the largest rotor made. Now used by all the leading up-to-date automobile and motor manufacturers throughout the country.

SOLE MANUFACTURERS

TINIUS OLSEN TESTING MACHINE COMPANY

500 North Twelfth Street
Philadelphia, Pa., U. S. A.

FOREIGN REPRESENTATIVES—*Messrs. R. S. Stokvis & Fils, Paris, France; Brussels, Belgium; Rotterdam and Amsterdam, Holland. Edw. G. Herbert, Ltd., Manchester, Eng. Andrews & George Company, Tokyo, Japan.*

There is only one best in every field

— and the *best* always gives better service — better satisfaction.

MUELLER Brass and Copper Tubing

is the *one best* product for those who use Brass or Copper Tubing — ***best by test.***

The reasons for Mueller leadership

Accurate laboratory control of every heat — plus three generations of uninterrupted experience — and the firm determination to excel — these are the prime factors in MUELLER supremacy.

You can quickly prove the exceptional merits of MUELLER Brass Tubing and MUELLER Copper Tubing by actual test in your own factory.

We will gladly quote prices and deliveries on request.

MUELLER METALS CO., PORT HURON, MICH.

Sales Offices: New York, Philadelphia, Buffalo, Pittsburgh, Cleveland, Dayton, Detroit, Indianapolis, Chicago, Minneapolis, New Orleans, San Francisco.

Makers of "Red Tip" Brass Rod; Welding Rod; Brass and Copper Tubing; Forgings and Castings in Brass and Bronze; also Brass Screw Machined Products.

Associated with H. Mueller Manufacturing Co., Decatur, Ill., and H. Mueller Mfg. Co., Ltd., Sarnia, Ont. Makers of Water, Plumbing and Gas Brass Goods and Tools.

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Design your lubrication

When you design an engine, you design each part to do efficiently the job assigned to it; the same with any other element of car construction.

It's the same, too, with lubrication. Engineers agree as to the importance of lubrication; the most vital single factor in cost of maintaining and operating a car. And proper lubrication is largely a problem of design.

Proper lubrication means more than just oil film protection for working surfaces. It includes effective cooling; the cushioning and quieting ability of a lubricant; and most important, the function of effective piston lubrication with minimum carbonization.

Accurate lubrication is simplified with Sunoco Motor Oils; through a choice of a number of types; each type a pure, straight-run, wholly distilled lubricant. Sunoco is good oil to recommend.

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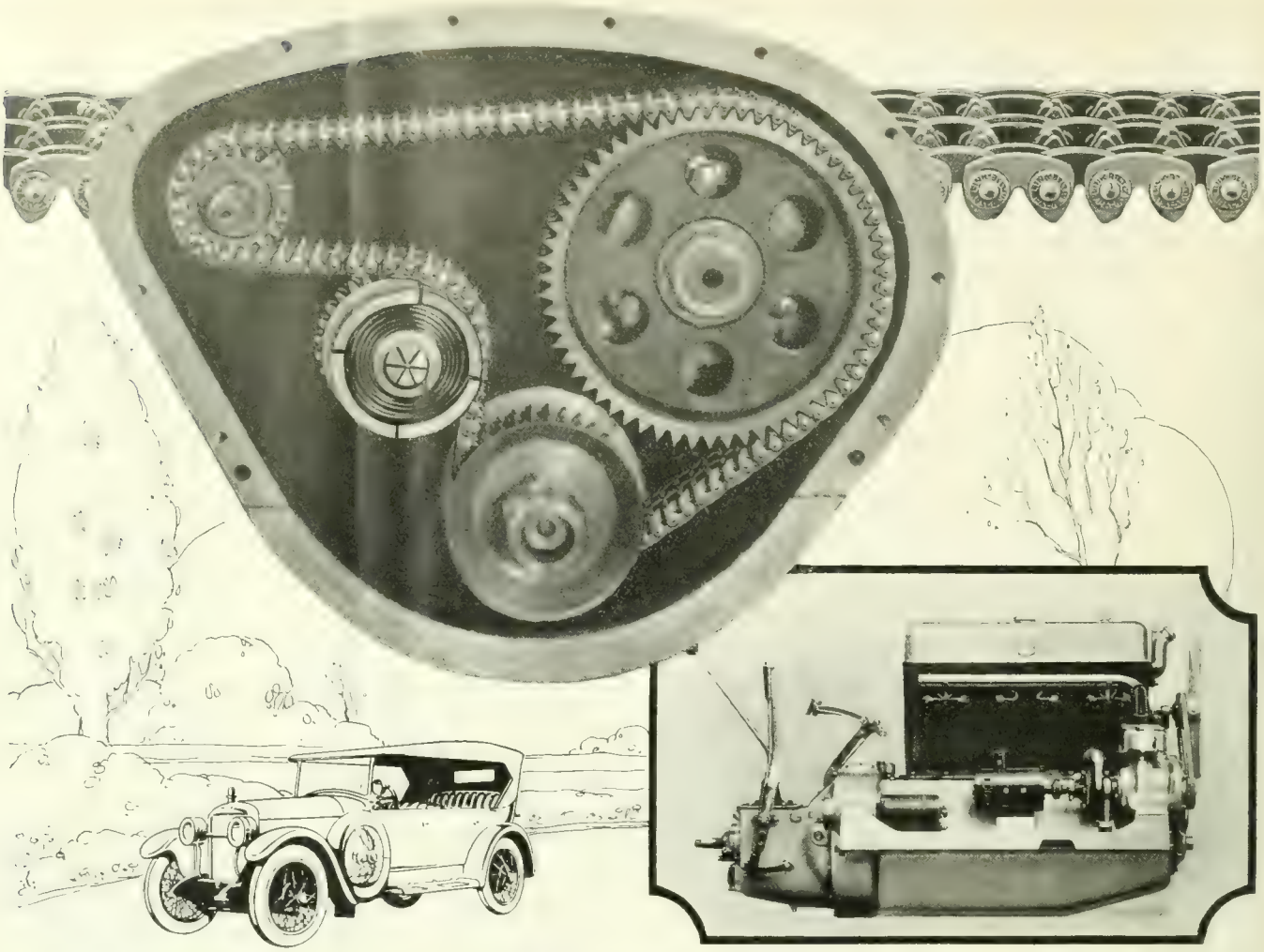

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